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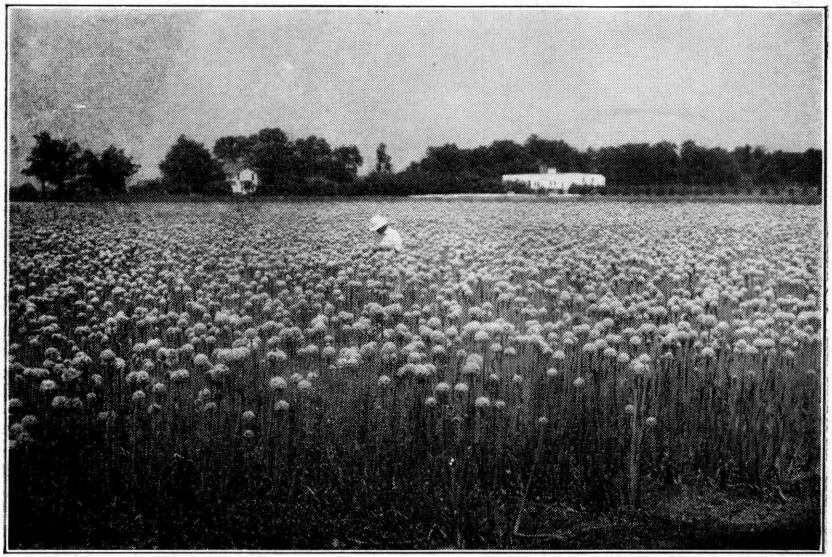
Onion Production in Ohio

Donald Comin



Inspecting onion seed umbels

OHIO
AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

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ONION PRODUCTION IN OHIO

DONALD COMIN

ORIGIN AND DEVELOPMENT

The onion has been used by man at least as far back as history records and is one of the earliest of cultivated plants, having been domesticated a very long time. This crop takes its name from the city built by Onias (B. C. 173) near the Gulf of Suez. The common onion is not now found in a wild state, although several wild species are native to North America. Peoples living in the general area of Southwestern Asia and in China grew the onion and from these centers it spread to other countries. It found favor for centuries with the Egyptians and Israelites as evidenced by writings and inscriptions on monuments (28).

Under long continued cultivation and selection the bulbs have developed into large shapely organs. They are grown in all temperate regions of the world, especially in Egypt, Spain, Italy, and the United States. By 1390, this vegetable was extensively used in Europe and was brought to this country by the earliest colonists. It is first mentioned as being cultivated in America in 1629. Vilmorin in 1883 described 60 distinct varieties and Tracy in 1901 tabulated 400 names of onion varieties (34).

The onion is a member of the lily family (*Liliaceae*), which includes only one other vegetable used today, i. e., asparagus (*Asparagus officinalis* var. *altilis*).

The genus *Allium* includes—besides the onion—chives, garlic, leek, shallot and Welsh onion. They are all herbs (soft, tender tissues) with a characteristic alliaceous odor which is due to the presence of allyl sulfide.

THE PLANT HABIT

Seed Germination and Seedling Development

In germination, the curved end of the embryo (the single cotyledon) starts growth and soon the primary root appears protruding through the seed coat. It is rare in monocots to have this type (epigeal) of germination. Close examination at time of seed germination shows the cotyledon in the form of a closed loop, with its tip still embedded in the endosperm and seed coat from which it obtains nourishment. On loose soils such as muck or sand the endosperm and seed coat are pulled from the ground, but on the heavier soils they may remain beneath the ground. This is commonly known as the "loop" stage. As soon as the cotyledon has absorbed all the nourishment within the endosperm, the tip or portion within the seed withers and becomes detached from the seed coat. This is commonly known as the "knee" stage. At the other end, or base, of the cotyledon where it joins the hypocotyl or exposed portion of the primary root, there appears a longitudinal slit; through this the first foliage leaf emerges. The cotyledon later disappears entirely.

Roots

The roots of the onion (except in seedling stage) are adventitious, unbranched, and arise from the stem plate which is at the base of the compressed conical-shaped stem. They are numerous and small, radiating in all directions from horizontal to vertical, forming a fibrous tuft. Roots continue to arise from this plate during the entire time the plant is growing. The root system is shallow, very few roots reaching more than 10 inches, with a few going to as much as 20 inches, depending on soil type. The lateral spread is 6 to 21 inches, with the main root zone within a 6-inch radius. It is evident that the feeding range of this plant is limited.

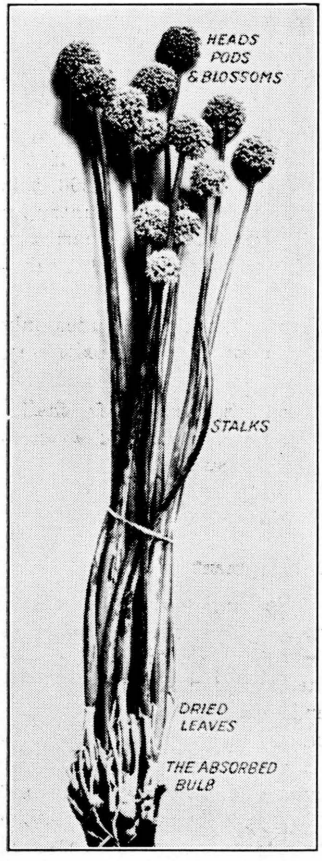

Fig. 1.—Mature 2-year-old onion plant.

Leaf and Stem

The leaves of the onion arise from a very short, conical-shaped stem plate at the base of the bulb. They possess parallel veins as is typical of most monocots. The outer leaves are the oldest and their swollen and expanded bases (sheaths) completely surround those within; the hollow blade proper arising from edge or rim of sheath. The leaf-bases after thickening become the "scales" of the onion bulb. The leaf blades are cylindrical and hollow.

Inflorescence

The flowers are regular and perfect and are borne in umbels on top of elongated stalks which usually reach a height of 2 to 4 feet and sometimes taller. There may be from one to as many as 20 of these stems or stalks. The umbel is enclosed within 2 or 3 papery bracts or sheaths which are split open by the pressure of the developing flower buds. The number of flowers in an umbel may vary from 50 or less to 2,000 or more. The buds in an umbel vary considerably in age and they do not appear in any definite order. In some species bulbels replace flower buds in the umbel.

Flower

The perfect flowers have an outer and an inner whorl of stamens, three in each whorl. The anthers of the inner whorl of stamens shed their pollen first, followed by the outer whorl and all pollen of each flower is shed within 24 to 36 hours.

The pistil has a three-celled ovary with two ovules in each locule. The style bearing the stigma develops later after all the pollen has been shed (dichogamy). The individual flowers of an inflorescence may continue to open over a period of 2 weeks or longer, and the whole plant may be in flower for 30 days or more.

Pollination

The flowers are almost entirely insect pollinated. The pollen is shed between 9 a. m. and 5 p. m. Inter-pollination among flowers of the same umbel is considerable since insects visit many flowers before leaving. Cross-pollination of onion flowers is, therefore, great and it is essential that different varieties, when grown for seed, be planted at least one-half mile apart.

Fruit and Seed

The fruit consists of a three-celled (carpeled) capsule, each carpel bearing two black seeds, convex on one side and almost flat on the other. The greater part of the seed is endosperm, the stored food material consumed by the spirally-twisted, cylindrical, thread-like embryo. The greater part of the embryo is cotyledon and within its cavity is the beginning of the first true leaf which later appears through a slit of the cotyledon.

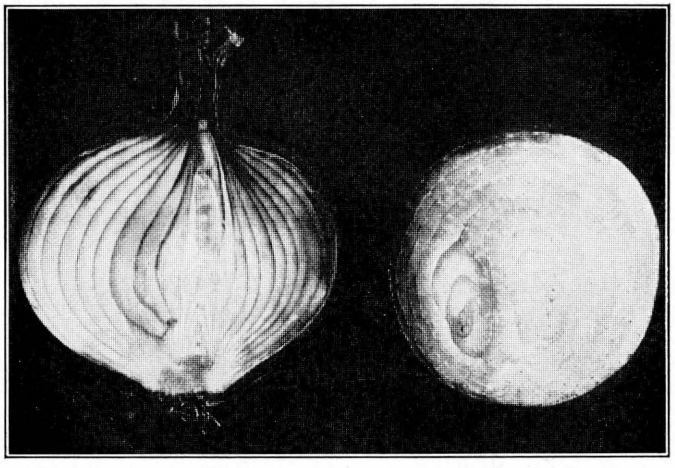

Fig. 2.—Vertical and cross sections showing onion layers and stalk bases.

THE ONION AS A COMMERCIAL CROP FOR OHIO

Most of the commercial onion crop in Ohio is produced on the muck soils of the State. In table 1 are given the acreage and production for the years from 1924 to 1943, inclusive. It is evident from the figures in this table that

TABLE 1.—Commercial acreage and production of onions in Ohio, 1924-1943 inclusive

Year	Acreage	Production	Year	Acreage	Production
	Acres	*Bushels*		*Acres*	*Bushels*
1924	6,240	2,184,000	1934	4,200	700,000
1925	3,460	1,031,000	1935	3,600	758,000
1926	5,300	1,367,000	1936	2,700	688,000
1927	7,000	2,352,000	1937	2,200	502,000
1928	6,550	891,000	1938	1,950	547,000
1929	7,860	2,138,000	1939	2,000	649,000
1930	6,770	1,970,000	1940	1,500	447,000
1931	5,300	874,000	1941	1,300	375,000
1932	5,140	1,388,000	1942	1,200	463,000
1933	4,610	991,000	1943	860	272,000

the acreage, production, and yield per acre of this crop have been decreasing steadily during the last 10 years. This trend is probably due to the fact that little or no new muck is being cleared for onion production and those areas formerly used for this vegetable are now planted to other crops.

As will be pointed out elsewhere in this bulletin, muck soils continuously cropped to onions, in time no longer produce profitable yields when in competition with higher yielding areas elsewhere in the United States. Although it might be possible to follow practices which would again increase onion yields on these old muck soils the cost at present would be prohibitive. The market garden production of onions on areas suitable and close to the larger cities will undoubtedly continue.

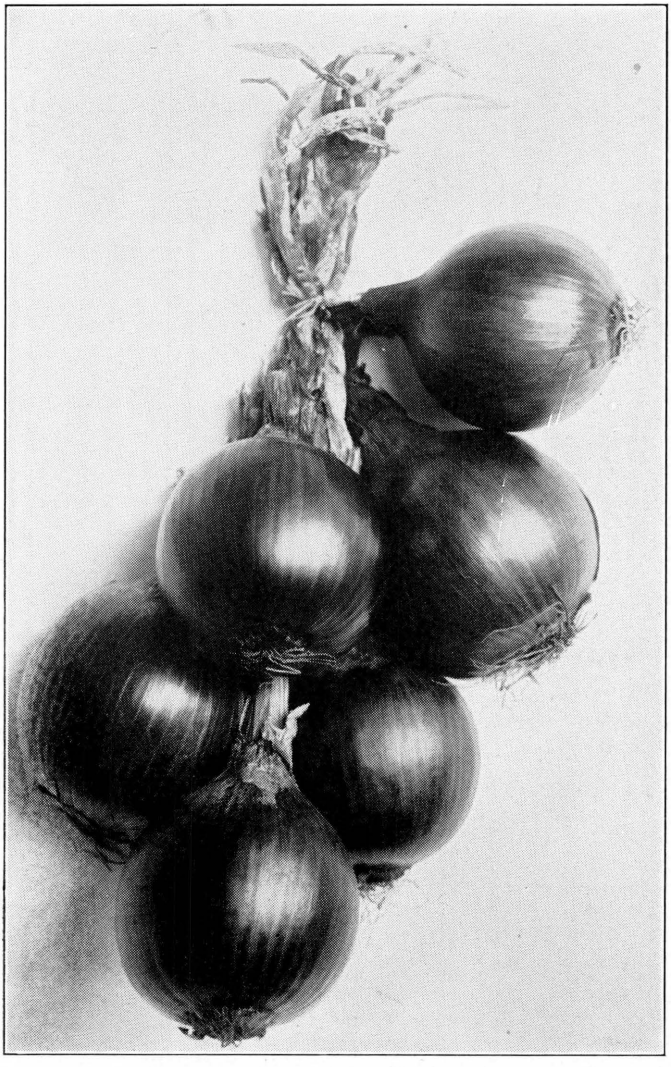

Fig. 3.—The Southport Red Globe onion.

ADAPTATION TO CLIMATE AND SOIL

The onion is adapted to a wide range of temperature and is frost tolerant. It is therefore grown practically everywhere in the United States. Extensive commercial production is confined, however, to the northern tier of states from the Atlantic Ocean to Minnesota, the West Coast, high altitudes of the Rocky Mountain area, and to the southern parts of Texas and Louisiana since these sections of this country are particularly suitable to this crop. The heaviest yields are obtained where cool temperatures prevail over a considerable time, permitting an extensive foliage and root development before bulbing starts. The crop requires fairly cool temperatures during the early stages of growth in particular, while during bulbing, harvesting, and curing, high temperatures and low humidities are preferred. It does not flourish outside the important onion districts, chiefly because the requisite cool growing season is too short and the temperatures become too hot or too cold for its best development.

The second factor of climate which exerts a powerful effect on the growth of the onion, although not entirely independent of temperature is the length of daylight or photoperiod. According to Magruder and Allard (31) the time when the onion plant will start to bulb is determined by the photoperiod and not by the age of the plant. The shortest length of daylight period necessary to initiate bulbing differs among varieties ranging from 12 hours for the extra early varieties to about 15 hours for the late types like Sweet Spanish. Early maturing varieties possess the ability to start bulb formation at short photoperiods and then to develop rapidly. In the North, the photoperiod reaches 12 hours or longer at the time of seeding and the extra-early varieties have no time in which to make large vegetative development before bulbing is induced. Provided the seed is sown in the greenhouse or hotbed early, large plants for transplanting are secured and after they are moved to the field a good yield of bulbs will result. The author (14) used this method of increasing yields of garlic and advised the fall planting of strains of garlic cloves which would withstand the northern winters and make considerable growth in the early spring before the photoperiod induced bulbing.

The late varieties of onions, besides having longer minimum photoperiods, develop more slowly than earlier varieties. They do poorly in the South because the photoperiod required for bulbing comes during extremely hot weather when sun scald, thrips, and pink rot combine to retard growth. Sweet Spanish is somewhat resistant to these troubles and consequently fair crops are produced in spite of the long growing period.

The effect of photoperiod is not entirely independent of temperature as shown by Thompson and Smith (38). Onion plants of the Ebenezer variety grown under three different temperature ranges but like photoperiod, matured in the normal length of time at the higher temperature range (70°-80° F.) but did not form bulbs at the lower range (50°-60° F.). However, high temperature alone was not effective in causing bulbing, because plants grown at ordinary day lengths in winter failed to bulb at either of the temperatures noted.

The onion and other members of its group generally thrive under a wide variety of soil conditions provided an abundance of moisture and fertility are maintained, together with good physical conditions. The wide adaptability of onions is illustrated by their production in the Connecticut Valley of Massachusetts, in the Red River Valley of Minnesota, in southern Texas, and in western

Colorado. Other areas of importance are New York, northern Indiana, northern Ohio, Michigan, and the Sacramento-San Joaquin Valley of California. Some of these soils are mucks, while others include sandy loams and heavy, dark calcareous soils, such as the Victoria soils of Texas.

Onions thrive on sandy loams when properly enriched with organic matter and fertilizers. They are especially well adapted to muck or peat soils which are naturally loose and friable, retentive of moisture, and cool in the root zone.

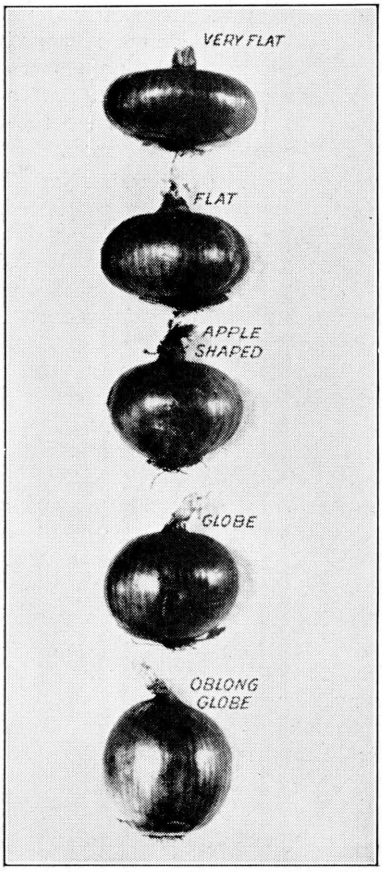

Fig. 4.—Some typical shapes of onions.

Onions are not adapted to the heavier soils such as clay and silt loams since these become too hard and compact for growth of either the seedling or the expanding-bulb stage.

TYPES AND VARIETIES FOR MANY USES

The Common Onion (*Allium cepa*) according to Bailey includes three botanical varieties; that is, *A. cepa*, the common onion propagated by seeds, *A. cepa* var. *solanium*, the potato or multipliers which are propagated by division of the bulbs and *A. cepa* var. *viviparum*, the top, tree, or Egyptian onions propagated by inflorescence bulblets or tops. Other species belonging to the genus *Allium* are Garlic (*A. sativum*) Leek (*A. porrum*) Chive (*A. Schoenoprasum*) Welsh onion or Ciboule (*A. fistulosum*) and Shallot (*A. ascalonicum*).

Onion Varieties

Onion varieties may be divided into American and European. The former are the hardy, late-maturing, long-keeping varieties that are grown mostly in the northeastern and central States. The bulbs have a firm, dense texture and are rather strongly flavored. The European varieties are of the Spanish and Bermuda types, less hardy than the American varieties and milder and more tender. The bulbs are large but do not keep too well nor long. They are grown mainly during the winter in the South and Southwest where they make considerable vegetative growth during the short winter days before the longer days of spring induce bulbing. The demand of the American public is slowly shifting towards the larger milder varieties, and for satisfactory results with these varieties in the North they must be started early under glass or the seedlings must be secured from the South and set out as soon as the weather permits. Also included in the European group are the Italian types such as Italian Red and California Early Red.

Magruder and others (32) (1941) described types of 21 principal American varieties of onions (including a few so-called European varieties such as the Italian Red Strain) which include between 85 and 95 percent of the total of onion seed sown in the United States. The list also includes the major types grown in all sections of the United States even though the volume of seed used may be relatively small. Probably 75 percent of the bulb crop consists of yellow varieties.

Brief descriptions of those onion varieties suitable for growing in Ohio are given here in order that the grower may select the variety or varieties best suited to his conditions of temperature, soil, and market. The reader is referred to Magruder's work for greater detail on the characteristics of important onion varieties.

At the State Muck Crops Experiment Farm, McGuffey, Ohio, several onion varieties were grown to determine the yield and usefulness under Ohio conditions. In table 2 are given the summarized results of these tests. It may be noted that Sweet Spanish is a heavy yielder and is being planted in larger acreages in Ohio. Seed grown in Ohio or in the same general locality has tended to result in larger yields of onions than seed of the same varieties grown elsewhere in the country. (See section on seed production.)

TABLE 2.—Weight comparison of onion varieties grown on muck in Hardin County, 1932

Variety	Data submitted by	Source	Yield per acre
			Bu.
Sweet Spanish	Ferry-Morse Seed Co.	California	557
Ohio Yellow Globe	J. B. Stambaugh	McGuffey, O.	556
Ohio Yellow Globe	Dexter Brigham	Michigan	553
Red Wethersfield	Ferry-Morse Seed Co.	California	537
Extra Early Barletta	Ferry-Morse Seed Co.	California	446
Ohio Yellow Globe	Wm. McGuffey	Michigan	444
Australian Brown	Ferry-Morse Seed Co.	California	428
Mammoth Silver King	Ferry-Morse Seed Co.	California	405
Extra Early Red	Ferry-Morse Seed Co.	California	397
Ebenezer	Ferry-Morse Seed Co.	California	389
Yellow Danvers	Ferry-Morse Seed Co.	California	386
Yellow Dutch Strasburg	Ferry-Morse Seed Co.	California	353
Yellow Globe Danvers	Ferry-Morse Seed Co.	California	321
Ohio Yellow Globe	Ferry-Morse Seed Co.	California	308
White Portugal	Ferry-Morse Seed Co.	California	308
Southport White Globe	Ferry-Morse Seed Co.	California	301
Southport Red Globe	Ferry-Morse Seed Co.	California	284
Prizetaker	Ferry-Morse Seed Co.	California	258
Southport Yellow Globe	Ferry-Morse Seed Co.	California	248
White Queen	Ferry-Morse Seed Co.	California	150

Additional information on the yield of onion varieties and strains, showing the variability in yield that may be expected on muck soil, was secured during 1933 at the same location. In table 3 are given the yields from four similarly treated plots, and the mean yield. Some of the variability in yield between replicates is due to soil variability and some to the stand variability and the number of onion thrips from plot to plot.

American Varieties

Of American varieties, the Southport Yellow Globe is probably the most important single variety of yellow onion for market and storage. It is a standard midseason to late variety well adapted to all northern onion-growing sections and produces medium-sized to large, round to oval-shaped (deep

TABLE 3.—Weight comparison of onion varieties grown on muck in Hardin County, 1933

Variety	Replicate and yield per acre					Mean yield
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Ebenezer	322	493	477	456	544	458
Extra Early Red Flat	512	359	480	480	.....	458
Early Yellow Globe	501	488	549	517	632	537
Ailsa Craig	.....	691	764	461	1,067	746
Ohio Yellow Globe	442	399	638	750	649	576
Southport Yellow Globe	544	555	657	657	630	609
Southport White Globe 2196	458	480	523	498	584	509
Southport White Globe 1384	461	.....	480	632	490	509
Southport Red Globe	421	509	525	515	606	515
Red Wethersfield	490	440	531	525	552	508
Yellow Danvers Flat	431	482	488	488	595	497
Australian Brown	520	461	480	549	517	505
Yellow Globe Danvers	391	509	512	517	466	479
White Portugal	415	421	373	437	482	426
Sweet Spanish 0377	758	721	442	847	890	732
Sweet Spanish 1266	796	737	.....	657	943	783
Sweet Spanish 2188	777	555	750	764	681	705
Sweet Spanish 2242	641	847	1002	.....	686	794
Sweet Spanish 2439	927	716	761	793	844	808
Prizetaker	833	740	887	850	935	849

globular) bulbs with many medium thick, medium yellow, dry skins that are well retained during handling and storage. The flesh is firm or hard and strong or pungent in flavor.

Magruder classifies Brigham Yellow Globe as a thicker and deeper-yellow scaled, longer keeping strain of the Southport Yellow Globe type. This strain has been selected over many years for improved keeping qualities by Mr. Brigham, an onion grower near Dexter, Michigan.

Ohio Yellow Globe is especially adapted for dry bulb production on the muck or peat soils of the northern portion of the country, especially on the black soils in the region of the Great Lakes. It is midseason to late in maturing and similar in shape to Southport Yellow Globe but with a more broadened, flattened base. This variety yields heavily and keeps well and resembles Southport Yellow Globe in all other respects.

Early Yellow Globe is a relatively new early-maturing variety selected from Extra Early Yellow which was originally selected from Yellow Globe Danvers. Its early maturity, about 2 weeks earlier than Yellow Globe Danvers, enables it to make a good crop in seasons when thrips severely damage later maturing varieties. It is rapidly supplanting Yellow Globe Danvers and in some of the muck soil areas of New York it is now the most important variety grown from seed. It is a second early, slightly flattened globe-shaped onion with deep colored and tightly retained scales and a medium firm and strong flavored flesh. It keeps moderately well, that is, until sometime in January, if properly matured. Extra Early Yellow, although slightly earlier, produces smaller crops of more flattened bulbs of poorer keeping quality than Early Yellow Globe.

Yellow Globe Danvers is now being replaced by later maturing varieties producing greater yields and by earlier varieties such as the Ebenezer and Early Yellow Globe. Yellow Globe Danvers has always been midseason or medium late in maturity with slightly flattened to round medium sized bulbs with slender necks and excellent keeping qualities. The flat strain is now almost entirely replaced by the Ebenezer variety for the production of onion sets.

The well-known Ebenezer variety is used almost entirely for the production of yellow onion sets because of their nearly round shape and bright yellow appearance and their excellent keeping qualities. The crop grown from Ebenezer sets matures early, is of good size, color, and storing quality. It has wide use all over the northern part of the country, especially by market and home gardeners for the production of bunch or green onions. This variety may also be used as an early crop from seed and will produce medium to large deep-flat, thick-skinned, dark yellow bulbs readily accepted by the trade.

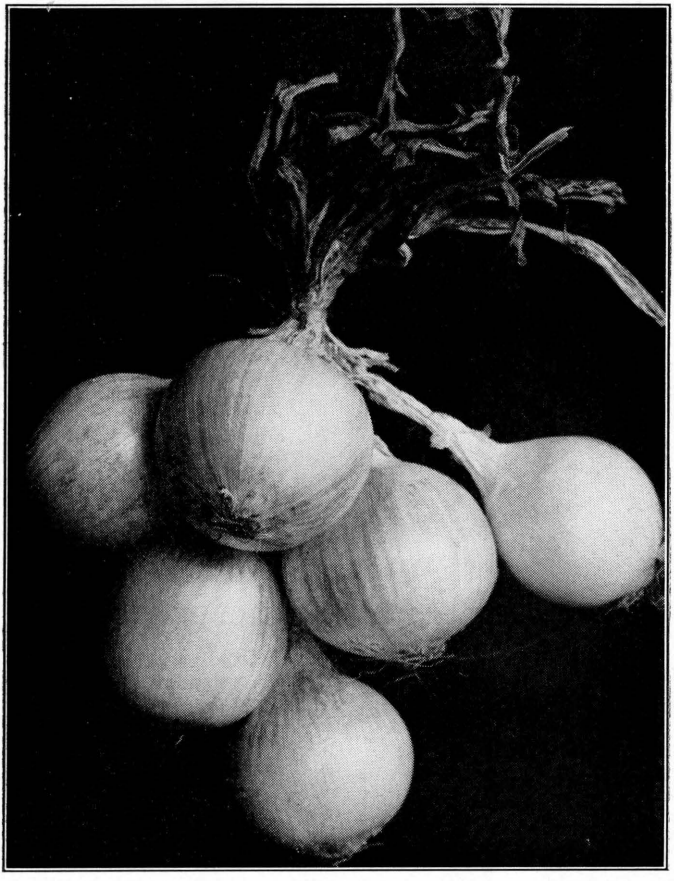

Fig. 5.—The Southport White Globe onion.

Southport White Globe is the most important white variety for the production of dry bulbs for market and storage. It is the most popular white variety in all northern onion growing sections where it usually commands a premium on the market over either the red or yellow varieties of the same shape. While very productive and a good keeper, it is inferior in this respect to the colored varieties. It is extensively used in market and home gardens for the production of green bunch onions from seed since less skinning is required

to produce the desired white bulb or basal swelling. It is midseason to late in maturity, produces medium-sized slightly-flattened to slightly oval-shaped bulbs which are preferred for dehydration and manufacturing purposes, because of its high dry-matter content, lack of objectionable color and high flavor or pungency.

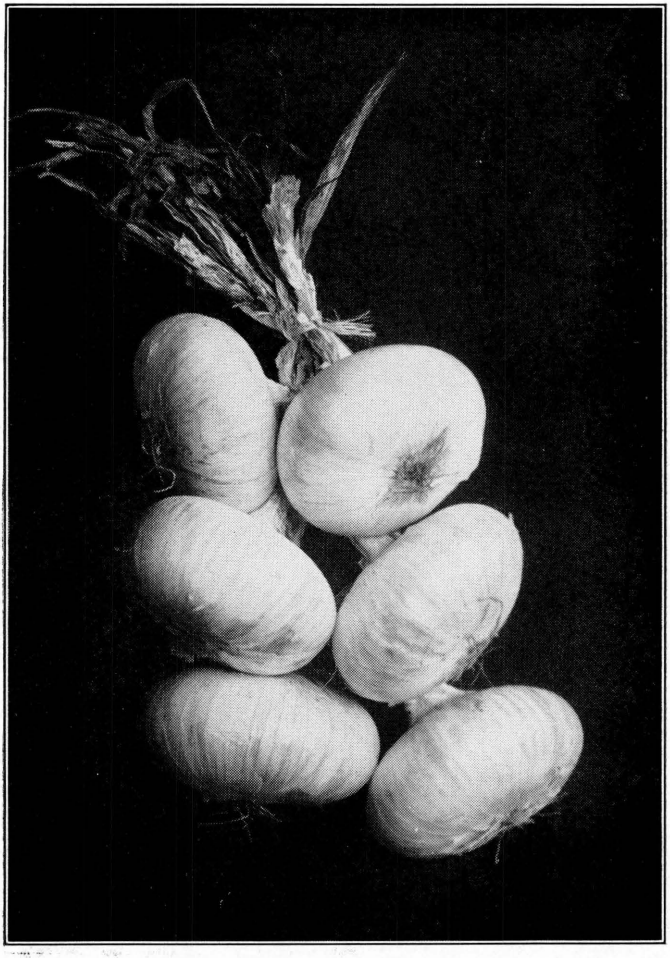

Fig. 6.—The White Portugal onion.

White Portugal or Silverskin is the most widely used white variety for the production of dry sets, and pickling sizes. It is used to some extent as a green bunch onion by market gardeners who also allow those plants not sold as a bunching onion to mature as white bulbs for market. It is a good white storage variety but not as productive as Southport White Globe. Midseason to late in maturity, the bulbs are small to medium-sized, semi- or slightly flattened, and very strong in flavor.

White Barletta is a small, extra early, white variety which keeps well and is grown in a limited way for pickling.

Bottle onions, so named because of their elongated shape, are grown in a limited way only by home gardeners. They produce the longest white edible portion in the green bunching stage of any onion grown for this purpose and may be planted as seed or sets and used as a green bunching or dry bulb onion. They are very mild in flavor and keep exceptionally well in the ordinary house basement without shriveling or sprouting. The bottle onion has gained more recognition in Ohio and Pennsylvania than elsewhere.

Southport Red Globe is the best of the red varieties for the production of dry bulbs for market and storage. Midseason to late in maturity, the bulbs are round to oval-shaped and the bulk are sold in southern markets where discrimination against the color is not as great as in the North.

Red Wethersfield is used almost exclusively for the production of red onion sets. The sets are more nearly round and keep better than sets of other red varieties. This variety is seldom planted for dry bulb production as it is deep or thick-flat in shape and only a fair storage variety.

California Early Red may be grown in all northern onion-growing sections although its commercial production is now confined to the early intermediate crop of central California because of its non-bolting characteristic under western climate. The bulbs are medium to large size and thick-flat in shape. The flesh is soft, easily bruised and mild in flavor and the bulbs must be consumed immediately.

European or Foreign Varieties

The so-called European onion varieties of the Spanish and Bermuda types are rapidly coming into favor with northern consumers and will undoubtedly be grown in greater quantity in the North as strains are developed which mature well from spring-sown seed and under relatively long photoperiods. Their keeping qualities should also be improved to enable them to compete with the standard storage varieties.

Sweet Spanish, formerly known as Valencia, is the most popular of the mild-flavored or European types among northern growers. The Utah strain of this variety is becoming more popular than the earlier Riverside strain from which it was developed by the Utah Agricultural Experiment Station. This onion is somewhat resistant to damage by thrips and as a consequence it is finding favor in the North when grown from seed or green plants, and is replacing the former favorite, Prizetaker, of the Denia type. Some care must be exercised in curing Sweet Spanish in the North as even when well cured it keeps only until January.

The dry bulbs are large, round to slightly oval-shaped with brownish-yellow medium outer scales and lighter inner tissues. Its large size and mild, sweet flavor are responsible for its popularity with the trade.

White Sweet Spanish is slightly earlier maturing, of about the same shape or slightly flatter than Sweet Spanish, and has clear white outer scales. As it increases in popularity, it is displacing in certain areas Southport White Globe for bunching and dry bulb purposes.

Onions Propagated Vegetatively

The onions propagated vegetatively are of two types: Those propagated by division (*Allium cepa* var. *solanium*) known as the multipliers, the potato onion being a hardy multiplier; and those propagated by inflorescence bulblets or tops (*Allium cepa* var. *viviparum*) known as top, tree, Egyptian, or perennial tree onions.

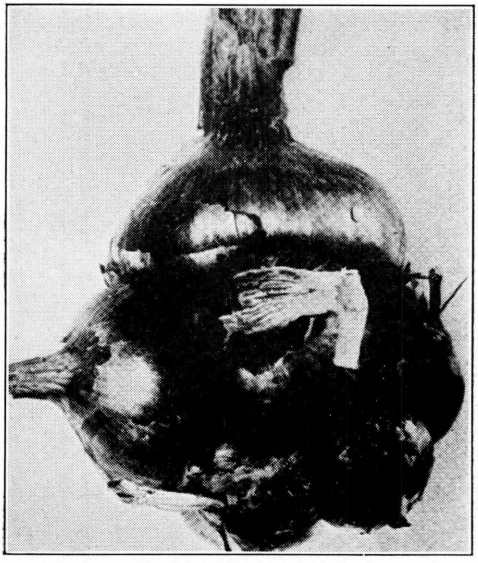

Fig. 7.—Multiplier or potato onion.

The multiplier or potato onions have compound bulbs formed from the segregation of the large mother bulb. Each bulb in the compound bulb produces 6 to 12 stalks. The name potato, applied to the hardy sort sometimes called English or yellow multiplier, originates from its method of propagation which was likened to the potato tuber and dahlia root. There are white, yellow, and copper-yellow varieties in existence. Their principal use is in the production of green bunch onions for early market. In the Southern States the segments from the division of the mother bulbs are set in the spring and produce large, firm, dry bulbs of fair keeping quality. In the North they are set in the fall and with some winter protection they produce the earliest bunch onions. These onions are of limited commercial importance as the flavor becomes very strong and the flesh tough in hot weather. There is another multiplier known as the Jersey Shallot which produces numerous small bulbs at its base and is used extensively in England and on the Continent as a seasoning onion. It is more often sold in this country under the name of multiplier and may be yellow or red in color.

The top, tree, Egyptian, perennial tree, or Catawissa onion produces clusters of bulblets at the top of the scape or seed stalk. Some primordia develop into flowers and others into bulblets. In some cases, all the primordia may develop into bulblets, and again all may develop into flowers. Bulblets may be produced in separate clusters one above the other on the same stalk. They may germinate while still attached to the inflorescence.

They are a hardy sort, producing bulblets or top sets in late summer, which are planted in the fall in the North to produce very early green onions. The old plants divide at the base, forming clumps, so that the sets are never used for the production of "dry bulbs." Home gardeners use this onion to a limited extent. No superior stocks are catalogued at present. There is, in addition, a type of "top set" onion which, when the sets are carried over winter and planted, make large, firm, dry bulbs.

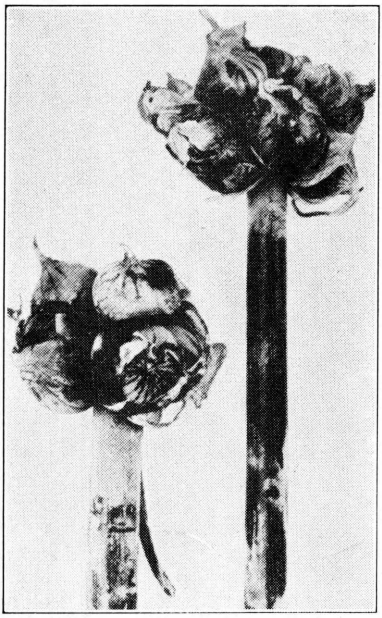

Fig. 8.—Summer top sets on the perennial tree onion.

Other Species

Of the remaining species in the genus Allium, five are of commercial importance as vegetable crops. Garlic (*Allium sativum*) is a hardy perennial plant native to Southern Europe and used largely as flavoring of other foods. The bulbs are compound, being composed of several (9 to 10) small, elongated bulbils or "cloves", all of which are enclosed by papery leaf bases instead of fleshy ones, as in onions. The leaves of the plant are solid and flat instead of round and hollow. The flowering head bears many small bulblets among the small long-stemmed flowers but no seed. Bulblets will produce new plants, although the cloves are used for commercial reproduction exclusively. There appear to be two distinct varieties commonly planted; the Creole (Louisiana or Mexican) and the Italian. The former has a broader, darker green leaf, shorter stem and larger cloves than the Italian but it is not as good a keeper. The California Station has improved strains of the Mexican (early) and the Italian (late) as well as many foreign introductions. The only hope for improvement is through bud mutations. There are Italian strains which are winter hardy in the North and since they bulb under shorter daylight periods than most onions, larger bulbs can be produced in the North by fall rather than spring planting (14).

Chives or Cives (*Allium schoenoprasum* is a hardy perennial grown for its leaves, which are used for seasoning and to a certain extent it may be used in borders as an ornamental. This plant bears many white, small, narrow, oval, clustered bulbs with membranous coats. The slender hollow leaves are borne in dense tufts and may be cut and used at any time during the summer. This plant flowers profusely, producing rose-colored blooms but seeds rarely. It is propagated by division of the tufts of bulbs, which should be lifted, divided, and replanted every 3 or 4 years. Potted clumps may be moved to the house and grown during the winter months. Wild plants are found in the northern tier of states and in Canada. No distinct varieties are known at the present time.

Leek (*Allium porrum*) is a biennial grown for its blanched stems and leaves. It produces a sheaf of leaves rather than a bulb, although the leaf bases are slightly swollen. The edible portion is made up of the lower parts of the flat solid leaves and when well-grown and blanched they are mild and tender. The leaves are used for seasoning. As the long white portion is most tender and salable, they are usually blanched with earth and marketed in bunches like green onions. The varieties catalogued by American seedsmen are not very distinct and include Large American and London Flag, Scotch Flag, Giant Carenton, and Large Musselburgh. These varieties are taller but somewhat smaller in diameter than a group now seldom catalogued and known as Rouen. Propagation is by seed.

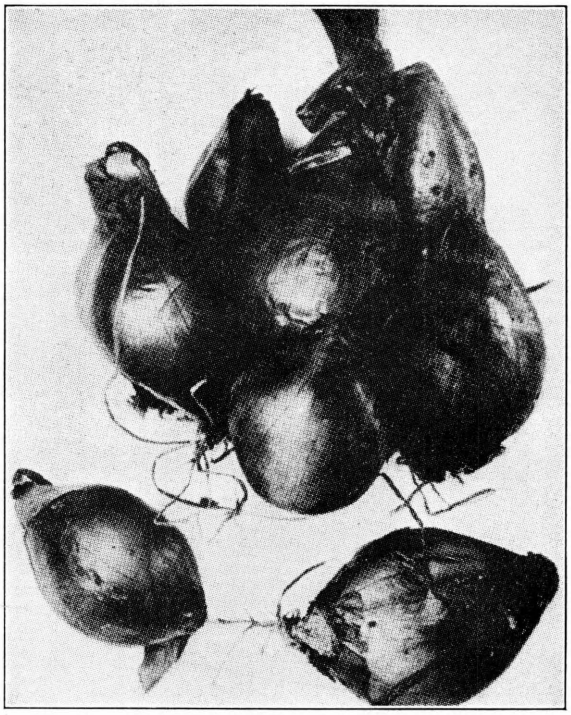

Fig. 9.—Shallots.

Shallot (*Allium ascalonicum*) is a perennial seldom producing seed. It produces small, oblong-pointed bulbs about 1 inch in diameter and 2 inches long borne in clusters (compound bulb). The single bulbs are known as cloves and are joined only at the base and are not surrounded by a thin membrane as is the garlic. The leaves are short, cylindrical, and hollow. The flavor is more delicate and milder than that of onions. Shallots are shipped from the South during late winter and are used both green and dry for seasoning and as a green onion.

Welsh or Japanese Bunching onion, sometimes listed as Cibol or Ciboule (*Allium fistulosum*) is a perennial but grown as an annual or biennial. The

plants have long fibrous roots and grow in clumps. No bulbs are produced, mere swellings occurring at the base of the plant. This plant resembles chive in habit of growth but the size of the leaf is more like the onion. Welsh onions may be propagated by division or by seed, the latter being preferred. The seed is sown in the spring and will produce onions for green bunching purposes ahead of those produced from onion sets. Some prefer to sow in August and hill the plants for winter protection and to produce a greater length of blanched portion for sale in the spring.

There are several types of Welsh onion although only two, the white Welsh and Nebuka are listed by seedsmen. The Nebuka type is used a great deal by plant breeders in their efforts to develop onion varieties resistant to thrips, pinkroot, and smut.

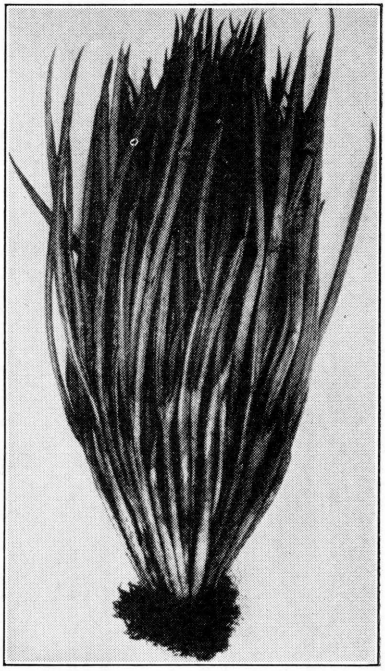

Fig. 10.—Welsh bunching onion.

GROWING EARLY, INTERMEDIATE, AND LATE CROPS

The onion is cultivated everywhere in this country as a home garden and market garden crop. Of considerable importance in local production is the green or bunching onion, the earliest being produced from Egyptian tree or "top" onion in the North. The second early crop is produced from dry "sets" and may be followed by large, mild, green onions produced from plants or seedlings of the foreign, mild-flavored varieties. A still later green onion is produced from successive sowings of onion seed in the open ground.

Seed for the production of dry bulb onions is sown at different times of the year in different parts of the country. Extensive commercial production is confined to special regions. In Ohio an early, intermediate, and late crop may be grown on separate areas of ground. Sets and seedlings (plants) are used to some extent in an effort to obtain early onions as well as seed sowings of early-maturing varieties. At present it seems unwise to attempt to grow onions from both sets (or seedlings) and seed in the same locality as the thrips, multiplying to great numbers on the earliest onions, greatly reduce the yields of the latter crop. The use of a partially thrip-resistant variety such as Sweet Spanish eliminates this objection to using sets and seed in the same locality. The new insecticide DDT offers possibilities in controlling thrips.

The late or main crop as grown in Ohio is usually seeded directly in the field and harvested in August and September. This crop, most of which is stored, supplies the markets from September until late March or April.

Although it is possible through selection of the proper varieties and the use of sets, seedlings, and seed to produce several onion crops, each maturing

at a different time, it is only possible in any single locality to extend the maturity date by a few weeks; at the most, 2 months. For this reason the extensive commercial production of onions in each region of the country is confined to the production of that onion crop best adapted to climatic conditions prevailing in that region.

Early maturity seems to depend on the ability of the plant to start bulb formation at short photoperiods and to proceed very rapidly with the process after the minimum period for bulbing is reached. In the North it is impossible to secure good yields of the extra early varieties like the Bermudas, Early Grano, and Creole by sowing seed directly in the field because at the earliest that seed may be sown the day length has already passed the minimum for bulbing and only very small bulbs and consequently poor yields result. It is possible to start the plants under glass in a greenhouse or hotbed where they may grow to larger size before the minimum photoperiod for bulbing occurs.

The selection of variety for the production of extra early and early onion crops is of primary importance. Magruder and Allard (31) have grouped the varieties into classes according to the minimum photoperiod required to produce 100 percent normal bulbs, as follows: 12 hours, Yellow Bermuda, White Creole, and Early Grano; 13 hours, California Early Red, Yellow Strasburg, Ebenezer, and Yellow Danvers Flat; 13.5 hours, Early Yellow Globe, Mountain Danvers, Ohio Yellow Globe and Sweet Spanish Strain No. 1; 14 hours, Red Wethersfield, Southport Red Globe, and Italian Red; 14.25 hours, Yellow Globe Danvers; normal day (maximum of 14.9 hours) Sweet Spanish Strain No. 2. Most commercial varieties are not pure in their inheritance of factors (genes) that determine the minimum photoperiod for bulbing, and some plants that bulb at a shorter photoperiod than is characteristic for the variety always appear in any planting of the variety.

Lateness of maturity may be due to other factors besides long photoperiod requirement such as a slow rate of bulb development after the minimum photoperiod occurs. Sweet Spanish is more widely adapted than many varieties because of its resistance to high temperature (sunscald) conditions and its partial resistance to certain insects and diseases such as thrips and pinkroot.

Plant breeders have already developed strains of onions carrying the factors (genes) for resistance to diseases and insects and others that permit them to grow under a wider range of climatic conditions.

The yield of onions is also greatly dependent upon the amount of growth the plant makes before bulbing commences. It is therefore important that onions be planted as soon as weather conditions will permit and their subsequent growth hastened by all means possible. A high level of fertility in the soil, ample, quickly-available nitrogen, and other factors in good culture are means of insuring this rapid growth. On less fertile soils, it is sometimes essential that dry sets or seedlings be used to secure good yields.

Temperature, as well as day-length, plays an important part in determining the date of maturity. Thompson and Smith (38) found that onion plants of the Ebenezer variety grown under ordinary daylight during winter and spring, plus supplementary light till 10 p. m. did not react in the same way under different temperature conditions. At the higher temperatures (70°-80° F.) the bulbs formed and matured and the tops were dead while at the same time the plants at 60°-70° had bulbed and the tops fallen but were still green. At the same time those plants grown at 50°-60° showed no bulbing. However,

high temperature alone was not effective in causing bulbing, because plants grown at ordinary day-lengths at that season of the year failed to bulb at any of the temperatures noted.

An example of the effect of temperature on bulbing may be found in certain regions of the West, especially in the high altitudes, where the photoperiod may be much longer than the minimum requirement, and still bulbing may be delayed because of low temperatures. This enables varieties with short daylight requirements to make considerable foliage development before temperatures are high enough to permit bulbing and explains, at least in part, why certain extra early varieties produce well under long days in high altitudes and do poorly at the higher temperatures of the low altitudes under a similar length of day.

SOILS AND THEIR MANAGEMENT

The onion and closely related plants will thrive when grown on a wide variety of soil types, provided an abundance of moisture and fertility is maintained, together with good physical conditions. Commercial onion culture flourishes on sandy loam soils, on heavy dark calcareous soils, on silty and silty-loam soils and on muck soils. Special care must be exercised with the heavier soils that contain little or no sand and which tend to run together and bake after hard rains. A good supply of humus in the heavier soils reduces the tendency of these soils to become hard and useless for onion culture.

Because this crop has a fibrous root system with a comparatively limited feeding range and the plants are rather delicate while in the seedling stage, the soil must be fertile, friable, easy to work, retentive of moisture, and free of stones and rubbish which might interfere with cultivation and hand weeding. Level areas not subject to water or wind erosion insure full stands of healthy plants. Because muck soils provide these ideal conditions for the culture of this crop, they are preferred to other types of soil and large acreages of muck are devoted to the growing of onions. The yields are higher and the costs are lower than on upland soils, which also explains why most of the storage crop is grown on muck and peat soils.

Preparation of the Land

There are few truck crops that require as careful fitting of the soil as do onions. This crop does well only under intensive culture and although there is nothing unusual about growing the crop, close attention and frequent cultivation and weeding are essential; otherwise the cost of production will be greatly increased or the crop may be lost altogether.

New land is not adapted to onion growing until it has been worked 2 years with other crops, preferably those that receive considerable cultivation for weed control, such as corn, beans, or potatoes. The land should be plowed in the fall, and again in the spring, then numerous harrowings and doubtless some handwork will be required to get the soil in suitable shape.

Soils low in organic matter and those which tend to bake should receive heavy dressings of manure applied during the autumn after harvest of one of the crops mentioned. An alternative is to incorporate organic matter by plowing down winter or summer green manure crops. Soybeans are probably the best crop to be grown the first season. Buckwheat is the best substitute for soybeans. Within recent years growers have found that field or sweet corn

drilled in rows about 14 inches apart (every other row in grain drill) dropping seeds about 8 inches apart sometime before July and plowed down when seed bed should be prepared for fall seeding of rye is an excellent method of quickly incorporating much organic matter into heavy soils and those upon which legumes do not grow so well.

On liberally limed acid soils, one year's growth of sweet clover provides more material to plow under than a year's growth of any other crop.

Rye or wheat, alone or in mixtures with vetch, should always be grown as a winter cover crop, and rye is generally preferable to wheat. Five pecks of rye and 25 pounds of vetch constitute a good combination for late summer and early fall planting.

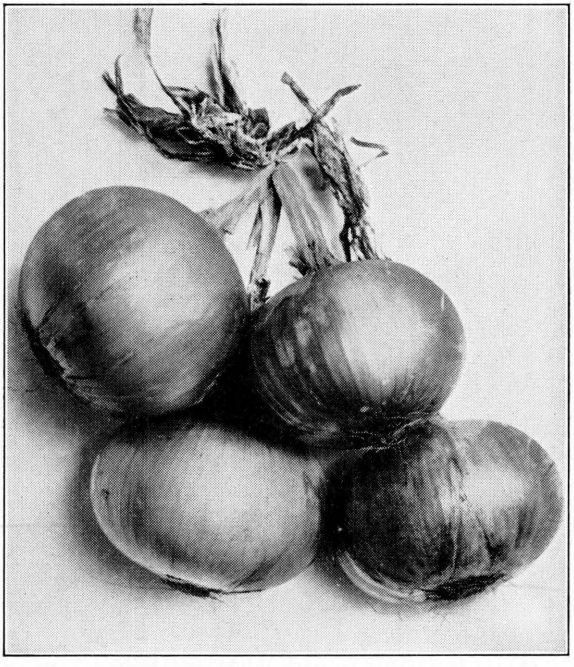

Fig. 11.—The Prizetaker onion.

The application of some fertilizer just before or just after plowing down a non-legume preceding onions is essential as it speeds the decay of the material low in nitrogen. Two hundred to three hundred pounds per acre of a nitrogenous fertilizer like sulfate of ammonia, nitrate of soda, or cyanamid should be applied broadcast on the field, and may be applied to rye 2 to 4 weeks before it is to be plowed under.

In those localities where late crops of onions occupy the ground until late fall due to late harvesting and curing in the field, it is not possible to grow green manure crops except in rotations. Under these conditions cover or catch crops must be depended upon for additions of organic matter each year.

Upland soils, however, will not produce good onion crops continually unless stable or green manures are used freely. Soil-improving crops may be grown even before the immediately preceding crop in a crop rotation and thereby become well mixed with the soil before the onion crop occupies the ground.

In spite of the high money value of an onion crop and the land upon which it is grown, growers would be further ahead financially if they practiced a system of field rotation whereby one-fourth of the farm produced a green manure crop each year.

Preparation of muck land for cropping to onions may include clearing off the forest growth, while if it is grass covered, the initial step is breaking. After the timber has been removed, the use of a muck area as pasture, for several years before breaking, allows the stumps and roots to decay and to work gradually to the surface where they may be more easily removed. Suggestions for clearing and breaking muck and establishing a sod are given in some detail by Harmer (20). A newly reclaimed raw muck is unsuited for the growing of onions until it has become more decomposed and compact.

Preparation of the Seedbed

Provided that the land intended for planting in onions is brought to a good mechanical condition by the incorporation of organic matter and the planting in other crops for a period of 2 years, the first step in the production of the crop is to plow moderately deep. The method of preparation will vary somewhat depending upon the character of the soil and the crops previously grown. Fall plowing is most common especially for heavy sods, new muck lands, and clay loams.

It is essential that the fertilizers be well mixed with the soil and that the seedbed be fine, firm, and thoroughly pulverized. The plowed soil must be repeatedly harrowed or disked, or both, and then rolled to compact and dragged to level until the soil is smooth and mellow to a depth of 5 to 7 inches. These operations properly managed will conserve soil moisture and will promote germination of many weed seeds and thereafter kill many weeds which can greatly reduce hand weeding costs later.

If plowing is deferred until spring, it should be done as soon as the ground is sufficiently dry so that plenty of time will remain for thorough working and the killing of weeds before sowing the seed. For land that has been plowed during the autumn and requires replowing in the spring, there are special disks well adapted to bedding it up and they will do the work rapidly. A Meeker harrow is especially well suited for the final working since it leaves the soil in a smooth even condition for receiving the seeds.

On muck soils under humid conditions, drainage is of particular importance and it is desirable that the system be capable of maintaining a water table at a fairly uniform distance below the surface (24 to 36 inches). Every effort should be made to keep the soil compact. Spring plowing will necessitate heavy rolling so that fall plowing or disking alone of loose muck is preferred. An extra heavy roller (600 to 700 pounds per foot) will be needed for the newer, lighter, and more fibrous mucks. Harmer (20) states that heavy rolling of muck will produce marked increases in crop yields. Only the heavy roller will compact the underlying layers sufficiently. Only on poorly drained or old mucks which have become compact and somewhat impervious to water is heavy rolling inadvisable.

Fertilizers for the Onion

The onion root system, compared with most garden crops, is rather meager in spread, in depth of penetration, and in branching (41). The more compact the soil the less the spread and penetration of the root system. Thus it is evident that the feeding range of the onion is limited. The best method of fertilizing this crop consists of building up the level of fertility in the soil rather than attempting to fertilize the crop by applying nutrients under the row on poor soils. It appears difficult to make a soil too rich provided the proper balance of the various nutrients is maintained. Because of this, it is usually advisable to have the soil tested periodically so that an intelligent fertilizing program may be followed.

Soils of several types vary widely in their natural fertility and in the the absence of an analysis of the quantity of available nutrients present it is impossible to make an accurate estimate of the fertilizer ratio to apply. Soil quick tests at least give the level of fertility based on a scale of high, medium, or low.

Manure

The onion is grown for its bulbous vegetative portion and not the fruiting portion and therefore requires a continuously available source of nitrogen during most of its active growing period. Animal manures serve the purpose well and are essential for the lighter upland soils. Applications as heavy as 20 tons to the acre have been made with no ill effects. The results of such applications may be realized over a period of 2 or 3 years. It is likely, however, that smaller applications of manure supplemented with commercial fertilizer would give still better results. Manure requires in the neighborhood of 75 pounds of superphosphate per ton of manure to balance properly the nitrogen and potash it carries. With manure already scarce in most parts of this country more reliance is placed in the green manure crops suggested earlier. On muck soils, green manures are preferred to animal manures for onions.

Commercial Fertilizers

To generalize on fertilizing the onion crop on suitable upland soils, good results have been experienced by growers when 1,000 to 1,500 pounds to the acre of 4-8-8 or 5-10-10 commercial mixture was used. On manured soils, a 5-10-5 is more suitable. As much as 3,000 pounds per acre of these mixtures has proved profitable in many instances. Commercial fertilizers should be applied either broadcast or with a grain drill shortly before sowing the seed. There is some new evidence to support the practice of plowing under one-half the fertilizer application and broadcasting the remainder before fitting the seedbed.

Fertilizing Onions on Muck Soils

Manure produces greater returns on upland than on muck soils and is therefore little used on the highly organic soils. The high nitrogen content it carries is slow-acting and of less value on muck soil which contains ample nitrogen as the soil becomes warm during early summer. Higher yields can be secured at a considerably lower cost with commercial fertilizers if the manure available is sold and the cash invested in mineral fertilizer. Muck soil has the characteristic of being naturally low in potash and this plant nutrient is more readily leached from the muck by rains than is phosphorus. The type of muck, the reaction (whether acid or alkaline) and the length of time under cultivation have a great bearing on the fertilizer program for onions.

Newly reclaimed muck (1 to 8 years) which is apt to be somewhat fibrous or woody requires heavy (1,000 to 1,500 pounds) fertilizer applications for onions. Usually no nitrogen is required and fertilizer mixtures such as an 0-20-20 or 0-10-20 are suitable. As the muck becomes older and well decomposed some nitrogen may be required in the fertilizer and a 2-8-16 mixture is suggested. If the soil has been heavily fertilized from year to year, 800 pounds annually may suffice. When the crop appears to be late in maturing the phosphorus should be increased to better balance the excessive nitrogen present. In this case the 0-20-20 is preferable to the 0-10-20 and occasionally a 3-12-12 mixture may be required.

The onion when grown on poorly drained, alkaline or shallow muck requires more nitrogen than on the more suitable mucks and should receive a 3-9-18 or 3-12-12 fertilizer. The 3-9-18 fertilizer mixture is also required on very strongly acid muck (pH 4.5 or less) which is low in calcium and will not produce onions and utilize the fertilizers applied unless some form of lime is also applied.

Fig. 12.—An excellent stand and spacing of onions. Note the large tops from which translocation of food to the bulbs will still further increase their size. This row, receiving sub-irrigation, yielded at the rate of 1,000 bushels per acre.

The method of application of commercial fertilizers for onions has been changing in the last few years from broadcast application to under the row application, particularly where the muck is moist during the period of active growth. From 400 to 500 pounds of the fertilizer should be placed 2 inches below the seed in the row, and the remainder of the fertilizer drilled in 7-inch drills previous to seed sowing. Onions are most frequently sown in rows 14 inches apart and by this method of fertilizer application the best possible distribution of the nutrients in relation to the young plants is obtained.

Recommendations for the use of fertilizers for onions on muck soils vary slightly, depending upon the location of the muck and those investigators reporting on tests being conducted. The practices followed in Michigan (20)

are similar to those given above. In New York an 0-12-18 is used in place of an 0-10-20 or 0-20-20 on new mucks, or a 3-12-18 if the muck is of the reed and sedge type. The latter formula is also suggested for older mucks upon which 1,200 pounds is applied instead of the 1,000 pounds applied to the newer mucks. In cool, wet seasons on the older mucks, side dressings of 150 to 200 pounds of some readily available nitrogen carrier will prove profitable. More fertilizer (1,500) carrying more nitrogen (4-8-12) is necessary as the muck approaches 20 years and older.

In Ohio and Indiana growers use from 800 to 1,000 pounds per acre of a 3-9-18 or a 2-8-16 fertilizer for early onions or at least twice as much potash as phosphoric acid. This analysis may be increased to a 3-12-15 where drainage is only fair or on muck less than 2 feet deep. Later plantings of onions usually receive no nitrogen except on land where the water table is high.

TABLE 4.—Response of onions to fertilizers on muck soil.* State Muck Crops Experiment Farm 10-year average, 1932-1941

Fertilizer treatment 750 pounds per acre	Yield per acre, bushels	Increase in yield above plot lacking in one element	
		Bushels	Percent
Nitrogen Series			
0-9-18	559	.....	.....
3-9-18	550	— 9	—1.6
6-9-18	550	— 9	—1.6
9-9-18	531	—28	—5.0
Phosphorus Series			
3- 0-18	476	.....	.....
3- 9-18	552	76	15.8
3-18-18	557	81	17.0
3-27-18	552	76	15.8
Potash Series			
3-9- 0	480	.....	.....
3-9- 9	519	39	8.1
3-9-18	547	67	14.0
3-9-27	552	72	15.0
3-9-36	552	72	15.0
No fertilizer	408	.....	.....
750 lb. per acre 3-9-18	465	57	14.0
1,500 lb. per acre 3-9-18	549	141	34.6

*A shallow muck (32 to 42 inches) under cultivation over 50 years; pH 5.6.

Results of fertilizer experiments in one location in Ohio reveal that an 0-9-18 fertilizer is as good as a 3-9-18 mixture. There seems to be no need on this soil for more phosphorus or potash than is carried in this 0-9-18 formula. There does appear justification for 1,500 pounds of this mixture as the increase from this application was more than twice that secured from one-half as much fertilizer, table 4.

Trace Elements Useful on Muck Soil

Deficiency of the minor or trace elements is comparatively uncommon. Usually, only muck soils exhibit any deficiencies when cropped to onions. Certain areas of muck soil produce onion bulbs of poor color and with thin scales. These onions have a poor appearance and they bruise more easily.

Knott in New York (29) found that onions developed scale characteristics typical of the muck soil on which they were planted, indicating an environmental factor was responsible for the unsatisfactory scale condition. The deficiency can be overcome by the use of superphosphate or of copper sulfate, the latter being the better treatment. An application of 200 to 300 pounds of powdered copper sulfate (bluestone) to an acre remedies the condition. Growers have reported increased yields from the use of copper sulfate although Knott was unable to show that this salt stimulated the growth of the onions. Instances have been observed where copper sulfate applications caused the crop to stay green longer than where no copper was applied. It is possible that the greater vigor of the onion tops, imparted by the copper, lessens the susceptibility to parasites which are responsible for premature ripening of the tops.

Fig. 13.—A poor stand of onions on muck. The small and missing onions were caused by maggot injury. Contrast with figure 12 photographed in the same general area.

In tests carried on in Michigan (20), it has been shown that at least 25 pounds of copper sulfate per acre should be applied each year until 200 to 300 pounds have been used, when no more need be added for several years. Greater quantities of this salt might prove harmful although moderate amounts have shown no ill effects on other crops grown in rotation with onions. The form of copper sulfate known as "snow" seems most satisfactory for use on muck soils. Definite increases in yields, color and thickness of scales, and flavor of onions have been noted where copper was used. The benefit seems to be correlated with temperature as the onion tops will remain green and healthy during hot-dry weather and will not die back at the tips (blast) as is characteristic of the onions grown without copper. The response to this salt is more pronounced on the more acid mucks, that is those with a pH of 6.2 or less.

Onions have responded to applications of manganese on both upland and muck soils near neutral in reaction. A striking increase in yield of this crop was obtained by the application of 30 pounds of manganese sulfate per acre on a silt loam soil, the reaction of which varied from pH 7.0 to pH 8.0 (19). In those instances where the plowing of shallow muck has brought up appreciable quantities of marl or clay bearing considerable lime, the availability of manganese in the soil is decreased to the point where onion yields are greatly reduced. The addition of sulfur will in time increase the acidity and make the manganese present in the muck more available. A less costly procedure is to apply 100 pounds of manganese sulfate per acre, preferably after the onions are 6 to 8 inches tall when the area affected by manganese deficiency may be determined. In order to obtain quick results when the soil is dry, it is better to apply the manganese sulfate in solution rather than to make a broadcast application and wait for rain to carry it to the root zone. Both copper and manganese may be secured in custom mixed commercial fertilizers which will reduce both cost and labor of making an application of these salts.

TABLE 5.—The response of onions to the application of minor elements on muck soil. McGuffey, Ohio, 1940

Minor element	Pounds per acre			Mean yield	Increased yield from minor element	
	50	150	250		Bushels per acre	Percent
Manganese	449	386	404	413	2	0.4
Copper	479	408	423	437	26	6.3
Es-Min-El*	472	494	461	476	65	15.8
Control	432	398	402	411	.....	.....

*Es-Min-El, abbreviation for Essential Mineral Elements, a product of the Tennessee Corp., is a mixture containing 55 percent manganese sulfate, 25 percent copper sulfate, 10 percent zinc sulfate, and 10 percent ferric sulfate.

The author has reported on the response of several vegetable crops to the application of minor elements in another publication (15). In table 5 are given the data with onions on a muck soil with a pH of 5.5 to 5.8. The response to manganese sulfate on a soil so acid was only 2 bushels per acre, showing no lack of manganese. Copper sulfate applications resulted in a 26 bushel increase in yield and therefore applications of copper are recommended for onions, using 5 to 10 percent in the fertilizers applied.

Lime as a Soil Amendment

There is considerable evidence that onions are not tolerant of acid soil conditions, that they thrive under a rather narrow range of pH or soil acidity values. Hartwell and Damon (21) were probably the first to point out that onions have a large lime requirement and therefore are the least tolerant of acidity, on upland soils.

On the other hand, many investigators have shown that onions will produce profitable yields over a range of soil reaction from pH 5.1 to 7.0. The best yields on upland soils, however, are most often obtained where the reaction is between pH 6.0 and 7.0, that is, on slightly acid soil. Lime applications will usually prove profitable on soils with a pH of less than 6.0.

TABLE 6.—The response of onions to the application of soil amendments on muck. McGuffey, Ohio*

Treatment per acre	Soil acidity at harvest		Stand 8 weeks after planting	Yield of onions in bushels per acre	
	1932	1933	1932	1932	1933
No treatment	5.5	5.6	100	178	620
2 tons lime	6.3	5.9	168	276	703
4 tons lime	6.6	6.2	124	225	660
6 tons lime	6.7	.....	122	191	.....
12 tons lime	6.9	6.9	.....	.....	547
½ ton aluminum sulfate	5.2	5.3	115	233	667
1 ton aluminum sulfate	5.1	.....	65	139	.....
¼ ton fine sulfur	5.0	.....	70	183	.....
½ ton fine sulfur	4.3	4.3	40	130	.....
¼ ton coarse sulfur	4.9	.....	122	208	.....
½ ton coarse sulfur	4.7	5.2	58	128	653

*Data supplied by J. D. Wilson, Department of Botany and Plant Pathology.

Muck soils will produce excellent onion crops with a pH as low as 4.6 which is considered strongly acid. These strongly acid mucks sometimes produce still better crops after the application of from 1 to 2 tons of ground limestone per acre (table 6). Very strongly acid mucks (pH 4.0-4.5) should receive from 2 to 6 tons of limestone and the intensely acid mucks (pH 3.0 to 3.9) will require from 5 to 10 tons of limestone per acre to produce a crop of onions.

Improving an Acid or Alkaline Muck

In connection with studies of the value of various soil supplements, such as lime, sulfur, and minor elements, in correcting the unproductive condition of strongly acid or alkaline muck soils, samples were treated with calcium carbonate or with sulfur in varying amounts and the change in reaction noted (11). The simple technique employed by Barnes (3) was followed. The results obtained are presented graphically in figure 14 and show the change in acidity which occurred after the completion of the reactions between the carbonates and soil acids and between sulfur and the soil bases.

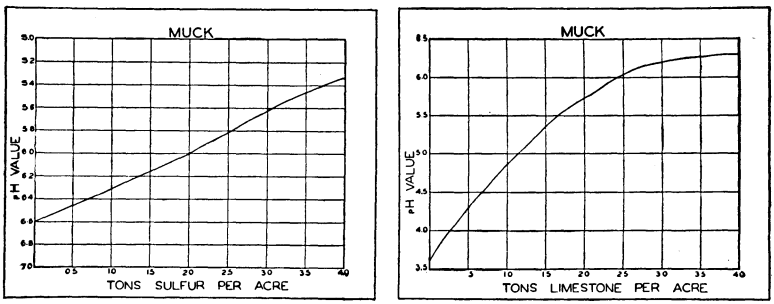

Fig. 14.—Titration curves for two muck soils.

Muck soils as acid as the samples employed are not common; however, the results show that considerable quantities of lime are needed to alter the reaction towards a more favorable pH. Although the reaction changes with time, it was practically completed at the end of 6 months. Those who are applying

½ to 1 ton of limestone per acre on their muck soils will note little permanent change in the soil reaction or in crop yields. The slope of the curve in figure 14 shows the need of somewhat more lime for a given change in reaction at the higher pH range.

Sulfur was added to the muck samples on March 15 and the pH readings were taken on September 15, February 5, and November 1. The change in reaction due to the sulfur was slow, and little change was noted on February 5 from applications up to 1 ton per acre. This was taken to indicate the presence of considerable carbonates in the samples which were being neutralized before any change in soil reaction occurred. The fact that muck soils vary in their content of calcium carbonate explains the wide variation in effects obtained from sulfur applications in the field.

It should be noted that muck soils show only a slight change in pH value for each unit of supplement added and are considered to be very highly resistant to any change in reaction. The amount of supplement necessary to effect any desired change in reaction may be estimated approximately from the curves by determining the difference between the quantities of supplement corresponding to the initial and desired pH values. These curves should be compared with those for upland soils (3).

Crop Rotation with Onions

The rotation of other crops with onions is desirable wherever possible and is assumed to prove beneficial largely due to the control of disease and insects and to the better use of the resources of the soil.

It is impracticable to outline a definite rotation to follow under all conditions. Experience of those who have definite information on the effect of one crop upon another (8) points toward the onion as being somewhat sensitive. It has been noticed that the lowest yield of onions follows those crops that remove the largest quantity of the deficient nutrients, and the highest yields follow those giving rise to the least acidity. The crops which most depressed the yield of onions, in order of this effect, were mangel beets, cabbage, rutabagas, potatoes, buckwheat, rye, red clover, corn, and onions. Ample fertilizing and liming of the soil tends in part to overcome the effects of one crop upon another. Extensive rotation experiments are now under way at the Muck Crops Experiment Farm, Hardin County, Ohio. The best advice that can be given is to alternate shallow-rooted and deep-rooted crops and to follow those that furnish organic matter with those whose culture favor its decomposition.

Muck areas that are continuously cropped to one vegetable may in time lose their productiveness in spite of all a grower can do to maintain a high level of fertility and the continuance of other good cultural practices (12).

Soil sterilization seems to remedy the adverse condition but as yet this practice is not economical under field conditions. Rotation of crops and the use of green manure and cover crops is, at present, the greatest aid in increasing onion yields on muck soils not lacking in available nutrients or other factors essential for good growth.

An example of this type of unproductiveness was studied in 1938 and 1939 at Celeryville, Ohio. The test vegetable was celery; however, the same results would probably have been secured with onions.

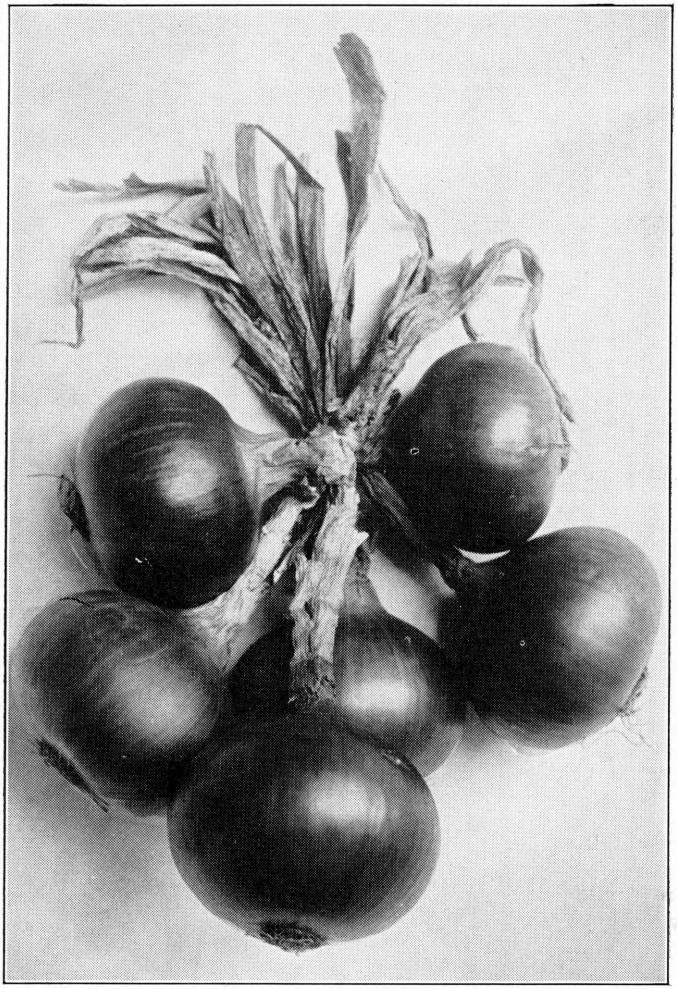

Fig. 15.—The Australian Brown onion.

Many growers have reported yields much inferior to those obtained in past decades. This unproductiveness always occurs on areas continuously cultivated for long periods, some as long as 50 or 60 years. It more frequently occurs where no rotation has been practiced and no green manure or cover crops have been grown.

In order to determine the cause of this unproductiveness, for two seasons various materials were applied previous to the growing of celery. If any nutrient or minor element was deficient, the crop's needs should have been satisfied, since all rare elements, as well as varying amounts of nitrogen, phosphorus, and potash, were supplied in such mixtures as Vigoro, Mineral Colloids, tankage, manure, and upland soil. The treatments and resulting yields

TABLE 7.—Effect of various soils treatments on celery yields on unproductive muck soils. State Muck Crops Experiment Farm.

Treatment	Amount of treatment applied, pounds per acre	Celery yields,‖ tons per acre
1938		
No treatment	.....	26.0
Fertilizer 3-9-18	1,500	31.5
Nitrate of soda	300	26.2
Muriate of potash	540	26.3
Superphosphate	675	24.4
Cyanamid	1,000	23.0
Manure	16,000	26.5
Vigoro*	1,500	27.1
Mineral colloids†	1,000	27.3
Fertilizer 3-9-18	1,500	27.3
Mineral colloids	1,000	18.4
Silt loam soil	6,000	25.4
Tankage	16,000	25.2
Minor element mixture‡	355	19.4
1939		
No treatment	.....	16.0
Fine ground limestone	500	14.0
Sulfur	500	14.7
Fertilizer	2,000	14.6
Minor element mixture §	1,000	14.6
Fertilizer 9- 9-18	2,000	15.7
Fertilizer 3-27-18	2,000	15.6
Fertilizer 3- 9-54	2,000	14.5
Fertilizer 3- 9-18	10,000	13.7
Fertilizer 3- 9-18	8,000	14.4
Fertilizer 3- 9-18	4,000	12.2
Fertilizer 3- 9-18	2,000	14.0

*A product of Swift & Company, Chicago, Illinois.
†A product of Soil Builders, Inc., Orlando, Florida.
‡Minor element mixture made up of 5 pounds boron, 100 pounds each of copper sulfate and manganese sulfate, and 150 pounds of magnesium sulfate per acre.
§Hydrated lime, manganese sulfate, copper sulfate, and borax, 250 pounds of each per acre.
‖Mean yields of duplicate plots.

as given in table 7 reveal only slight differences in yield irrespective of the treatment. Commercial fertilizer produced the only sizable increases, and these were variable from season to season. Quick soil tests also revealed the relatively high nutrient level existing in the soil.

In table 8 are given the increased yields obtained from sterilizing the muck soil.

TABLE 8.—The effect of soil sterilizing treatments on celery yields on unproductive muck soils. State Muck Crops Experiment Farm.

Sterilizing treatment and amount applied, 1940	Celery yield, tons per acre
No treatment	8.2
Cyanamid, 1,500 pounds per acre	22.1
Cyanamid, 2,000 pounds per acre	14.6
Cyanamid, 2,500 pounds per acre	9.1
Carbon disulfide, 40 cubic centimeters per square foot	10.5
Formaldehyde, 75 cubic centimeters per square foot	27.8
Larvacide emulsion, 3 cubic centimeters per square foot	32.7
Larvacide, 3 cubic centimeters per square foot	40.4

To determine whether the use of green manures in rotation with vegetables on muck would increase yields, a 2-year rotation of various muck crops and soybeans was started in 1940. The preliminary results indicate that plow-down green manures may prove valuable in improving this type of unproductive muck.

Green Manure Crops Beneficial to Highly Organic Soils

On one series of plots it was found that plowing down a full summer's growth of soybeans every other year increased the yield of onions by an average of 30 percent at the end of 4 years. The onion yields during 1944 were 722 bushels per acre on the continuously cropped plot and 934 bushels per acre on the plot planted to soybeans every other year. Other vegetables responded similarly with a 32.8 percent increase for celery, 14.3 percent for cabbage, 36.6 percent for sugar beets, and 14.7 percent for potatoes.

Since muck soils in general are very high in nitrogen after the soil warms up in the spring, it is questionable whether all of the beneficial effect of the soybean green manure crop could be attributed to the nitrogen it supplies. Whether lesser amounts of plowed down organic matter will continue to result in increased yields is yet to be ascertained.

PLANTING AND CARE OF THE CROP

The three methods of securing a crop of onions are sowing seed, planting seedlings, or planting dry sets. The method employed depends upon the locality, type of soil, and type of crop desired. A large part of the dry bulb onion acreage in the North is grown from field sown seed. Most of the onion seedlings shipped to the North each spring are sold to home gardeners and used only to a very limited extent by commercial or market gardeners. A few plant growers in the North raise onion plants in hotbeds or greenhouses for sale to home gardeners.

Sets are used for the production of green bunching onions, early crops of dry bulbs, and to a considerable extent for bulbs for home use by home gardeners in Ohio.

Growing the Crop from Sets

Home gardeners generally depend upon sets for their supply of green bunching onions and mature bulbs. The dry set is also of some importance in the commercial production of dry bulbs because it often results in an earlier crop and avoids the loss from onion smut. Larger yields are obtained from sets planted on upland soils, but this is not always true when they are planted on muck soil. The season has much to do with the relative results. Wet weather during the period of bulb enlargement more frequently reduces the yield of the crop from seed since it matures somewhat later than that from sets. The number of bulbs to a foot is greater in seeded onions, unless thinning is practiced, and this influences the yield. Dry sets are convenient to handle under conditions that are not favorable for good success with seed. More certain and satisfactory results may be expected from sets. The labor in thinning is eliminated, and weeding is reduced. A good comparison between the two methods over a period of 6 years made by Lloyd (30) in Illinois showed larger yields, earlier maturity, greater percentage of large onions, and greater gross returns and profits from sets. No comparable data were given for muck

soils. The cost of growing an acre under the set method was greater due to the increased cost of sets only, for the labor was somewhat less, as less tillage, weeding, and no thinning were required.

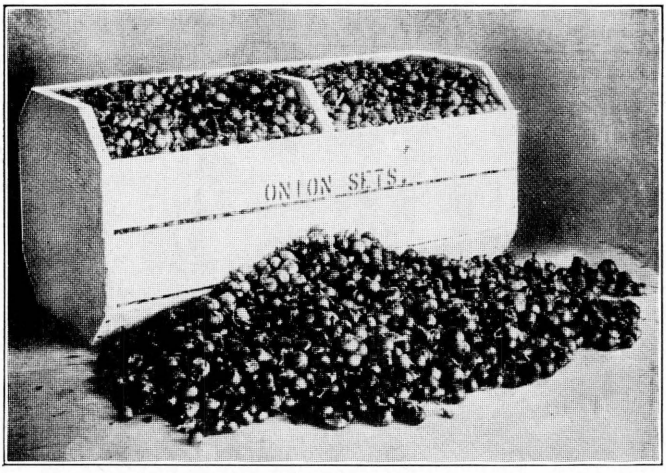

Fig. 16.—Onion sets as shipped in crates.

The growing of set, seedling, and seed onions the same season in any locality aggravates the insect problem because the onion thrip population is built up to a high level on the earliest crop and soon spreads to the later onions in greater numbers, reducing the yields in proportion. It has also been claimed that sets are not satisfactory on all muck soils. It has been found in Ohio that a lack of quickly available nitrogen is the cause for these low yields and where nitrogen fertilizers are applied the stored food in the sets is readily utilized in the formation of new tissues, and rapid growth results. The same reasoning probably applies to onion seedlings as well.

In table 9 are given results of nitrogen fertilization with onions grown from seed, sets, and seedlings. The data show that the onions grown both from sets and seedlings responded to a greater extent to the nitrogen increments than did the onions grown from seed.

Onion sets should be planted as early as the soil can be prepared, and may usually be planted 2 weeks before it is safe to sow seed in the North. Fall planting is unsafe in the northern climate except for multiplier onion sets. Early planting is important in all regions where the crop is grown during the hot weather and long days of summer because the yield will be definitely correlated with the amount of growth made by the plants up to the time when the days become long and bulbing starts. The time of planting has a much greater effect on the yield than it does on the time of maturity. This relation is discussed in connection with growing onions from seeds.

The actual planting of sets may be done by hand or by machine which opens the row, drops the sets, and covers them with soil. If they are planted for green onions they should be placed upright in trenches and covered with about an inch of soil. It is not necessary to place the set in an upright position if mature bulbs are being grown. It is rather expensive to plant sets by

TABLE 9.—The response of onions from seed, sets, and seedlings to varying amounts of nitrogen in the fertilizer applied to muck. State Muck Crops Experiment Farm.

Fertilizer treatment 750 pounds per acre	Yield of onions in bushels per acre		
	From seed	From sets	From seedlings
1932			
0-9-18	427	407	412
3-9-18	439	425	435
6-9-18	398	458	457
9-9-18	428	453	474
1934			
0-9-18	582	477	515
3-9-18	635	527	572
6-9-18	639	540	646
9-9-18	625	561	693

hand and therefore commercial growers are using one- or two-row set planters which open the row, drop the sets, and cover them with soil. To do a satisfactory job with a machine it is necessary to remove excess scales and to grade the sets into about three sizes to facilitate the adjustment of the planter. Rows may be marked for hand planting with a seed drill and the spacing of the sets estimated, or a marker with pegs or cross pieces for indicating places for the sets may be readily constructed. On the average, 10 men will plant an acre in a day, while one man with a planting machine will do the same. Sets from ½ to ¾ inch in diameter should be used since smaller sets do not contain sufficient food reserve, and larger sets go to seed readily. The removal of seed heads is desirable when large sets are used for planting. Even though a greater yield may be obtained in a shorter period from large sets than from medium sets, a greater net income can usually be expected when medium sets are used, because the crop will be more uniform and of higher grade, and because the initial cost is less on account of the smaller number of bushels required. The price of the different size and grade of sets would determine whether to buy them in the ½- to ¾-inch range or in the ⅜- to ⅞-inch range. It will be necessary to adjust the planter for each size. Fifteen to thirty bushels are required to plant an acre, the quantity depending upon the size of the sets. Beaumont, and others (7) give data on the number of bushels of Japanese sets of three sizes to plant an acre (table 10). The rows are usually spaced 1 foot or more apart with the sets spaced 1 to 2 inches apart in the row for green bunching onions and 3 to 4 inches apart in slightly wider rows for dry bulb production on upland soils. On muck, 2½ inches may be sufficient spacing in 14-inch rows, provided the fertility level is high.

TABLE 10.—Number of bushels of Japanese onion sets to plant an acre

	Size in inches	Weight in grams	Bushels of sets required per acre
Large	¾ to 1	6.3	94.98
Medium	½ to ¾	1.4	25.08
Small	¼ to ½	0.5	8.18

Growing Onions by Transplanting

The transplanting process is merely a modification of the regular seeding method. The advantages gained by transplanting are an earlier crop, a uniform stand, and bulbs of more regular size. Practically the entire crop of Bermuda type onions grown in the United States and the production of the Spanish onion in some sections are handled in this manner. This method is necessary in the North to secure large bulbs of these mild flavored kinds. Within the last 10 years, growers in the middle Atlantic States are having considerable success with the Utah strain of Sweet Spanish on muck soil by seeding directly in the field.

Where a small area is to be grown, the transplanting method is ideal, but for large areas the cost of plants and labor makes this method less practicable. After transplanting, the seedlings require water, and for this reason the method is mostly limited to areas where some form of irrigation is available.

Large numbers of transplants are grown in the South in the winter for shipment to the North during the early spring for use by home gardeners. Importation of plants may introduce serious soil-borne diseases and insect pests of onions, and other crops, and it is prudent to insist that imported plants be certified or inspected by authorities for cleanliness and excellence in the plant bed.

Those growers having greenhouse or hotbed space may grow onion transplants at the same time they are growing celery plants, sowing the seed thinly (a stand of 5 or 6 to the inch) 10 or 12 weeks before outdoor planting time. After the plants reach a height of about 6 inches they are clipped back occasionally to about 4 inches to keep the tops from becoming tangled and make the plants easier to handle.

The plants should be at least one-half the thickness of a pencil when transplanted, although moving them to the field should not be delayed because they have not quite reached this size.

Setting of the plants in the field is done by machine or by hand. From 100,000 to 125,000 plants are required to plant an acre when they are set 4 inches apart in rows 12 to 14 inches apart. When set by hand it is customary to use a dibble, while some growers have had success by opening a furrow and dropping the seedlings in place. In either case the soil must be well firmed about the roots. The plants should be 4 to 6 inches high and set into the soil from 1½ to 2 inches deep. Planting should not take place until the danger of severe frost is past, but no time should be lost after this period in planting the entire acreage as earliness is the dominant factor in success by this method. Watering is a great advantage after planting, although it is not necessary if the soil is moist.

Growing the Crop from Seed

The great bulk of onions grown in Ohio is produced from seed sown in the open ground where the crop is to mature. This system provides the lowest cost of production and is used almost exclusively for growing the late market and storage crop in the North.

Various types of seed drills are used to plant the crop, and for large acreages several drills are attached to one frame to form a gang seeder pulled by horses or tractor. A leveler or roller may be attached in front of the drills to level and compact the seedbed immediately before the furrows for the seed are made. Gang drill equipment spaces the rows accurately across the field so

that gang cultivating equipment can follow up in later cultivations with perfect alignment in relation to the onion rows. Small 2-wheel garden tractors have become very popular for planting and cultivating onions and other closely planted crops that used to be planted and cultivated entirely by 1-row hand-pushed equipment. Larger equipment is difficult to control in a field on onions, the rows of which are only 12 to 14 inches apart, and the seedlings of which are very small and not too well anchored by the meager root systems.

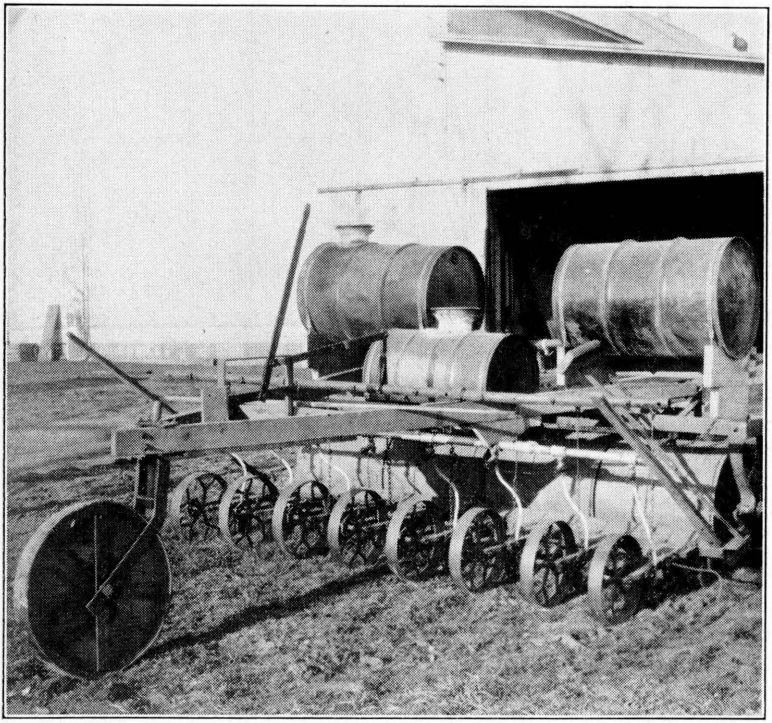

Fig. 17.—An 8-row gang onion seeder.
This seeder was developed in the Scioto Marsh area of Ohio and assembled by growers. The tanks are for formaldehyde solution used to reduce losses from smut (*Urocystis cepulae*). The seed hoppers have been removed to show the steel rollers, rubber tubes for fungicidal solution, and linkage for raising and lowering seeders.

Good seed is essential for securing as near a perfect stand as possible. The better the stand the less need there is for thinning out plants later on. The germination percentage and, if possible, the vitality of the seed should be known. This may be secured by counting and planting 400 or 500 seeds in a window box or seedling flat and then determining the germination and vitality, by counting the seedlings after 2 weeks time. The cost of seed is such a small proportion of the total cost of growing the crop that it is poor economy to use anything but seed of high vitality and germination. Experienced growers use extreme care in regulating the drills to distribute the correct quantity of seed

per foot of row as determined by its germination percentage, size, and probable later loss of plants. Under this method no thinning may be required, especially on muck soils where occasional crowding of the bulbs as they grow will do no harm.

In the North, seed should be sown as soon as the hard freezes are over. Early planting is of primary importance, especially where the crop matures during the hot weather and long days of summer. The best results are obtained when the seed is sown within 2 weeks after the soil first reaches workable condition in the spring. The plantings at the beginning of this period are more likely to result in larger average yields than later plantings. If the first period of good planting weather is allowed to pass there is no certainty of getting the onions planted sufficiently early for maximum yields. There is a tendency for the onion to mature about a certain time, regardless of the time of planting. Lloyd (30) in Illinois showed, over a period of 6 years, that a spread of 6 weeks in time of planting had a marked effect on yield but much less effect on time of maturity. The early plantings produced the largest average yield, crop value and profits as shown in table 11.

TABLE 11.—Influence of time of planting onions upon days to maturity, yields, crop value, cost of production, and profits—6-year average

Date of planting	Date of harvest	Number of days to maturity	Yield of onions, bushels per acre			Value of crop per acre	Cost of production per acre	Profits per acre
			Large	Small	Total			
March 27.....	August 12	137	324	22	346	$244	$102	$142
April 13.....	August 15	124	296	22	318	220	101	119
April 28.....	August 19	113	198	21	219	153	88	66
May 11.....	August 29	110	174	45	219	154	88	66

Where hand cultivation is practiced, the usual distance between rows is 12 to 16 inches with a preference for 13 or 14 inches under most conditions of soil and fertility. For horse cultivation, the rows must be widened to 24 or 36 inches, with a consequent reduction in yield; therefore, most growers resort to hand or garden tractor cultivation.

The quantity of seed required to plant an acre will depend upon the distance between rows, the purpose for which the onions are being grown, and the size of the seed. For pickling purposes, the amount of seed may be as great as 25 pounds to an acre. For the growing of standard market onions, the object is to secure a uniform stand of from 6 to 12 plants per foot of row, a good stand being dependent upon the size of the matured bulbs desired. A more fertile soil will support and produce more large onions per acre than one less fertile. To secure 6 to 12 plants per foot of row, a seeding of from 12 to 20 seeds is necessary; the number required depending on the percentage of germination, the vitality of the seed, the depth of seeding, the type of soil, the moisture supply, and the probable amount of disease and insect injury. With seed of good germination and rows 12 inches apart, this requires from 3 to 4½ pounds of seed per acre, depending on the size of seed. Rows 14 inches apart require 4½ to 5 pounds per acre, and in cases where the soil forms a crust above the small seedlings the larger quantity of seed should be used and thinning resorted to later when necessary. With the rows 3 feet apart, but 1¼ to 1½ pounds will be necessary. The newer types of large power equipment can handle rows from 12 to 30 inches apart.

In fairly heavy soils the seeds should be covered no more than ½ inch. Three-fourths of an inch is sufficient in most cases, while 1 inch will do no harm in very sandy types. On muck soils the depth of planting ranges from ½ to 1 inch, depending upon the type of muck. On a heavy muck, inclined to crust, ½-inch depth is preferable. On the better drained, more open mucks, ¾ to 1 inch is necessary to insure that the seed will be in moist soil.

Thinning the Crop

The objection to thinning onions is the expense. It is admitted that more large onions and fewer small ones will be secured from thinned rows, especially on upland soils. Unless the small onion plants are bunched in the row or spaced very close after the period of maggot damage has passed, thinning will seldom prove profitable, particularly during periods of relatively high labor costs. The careful grower can usually secure good yields of large onions by close estimation of seeding rate, soil fertility, and probable germination and survival of the seedlings.

Cultivation and Weeding

Weeds in onion plantings are controlled by cultivation, except those in the rows which must be removed by hand. These two operations may be kept to a minimum by proper preparation of the soil and prevention of weed seed development. Thorough and occasional working of the soil previous to planting, when time and soil conditions permit, pays large dividends later in relatively weed-free onions.

It is also essential to remove weeds while they are still young for the onion plant grows slowly at first and is readily injured by them. A weed destroyed in time saves much labor later, for as the weeds grow and spread they are much more difficult to remove. Onion weeding is the most laborious and most expensive operation connected with growing the crop.

In Massachusetts (9), a study revealed that an average of 21 days' labor per acre was required to weed onions. In addition, cultivating required 5 days and wheel-hoeing 4 days more labor, or a total of 30 man-days to care for the crop from planting to harvest.

Much experimental evidence (39) has shown the importance of weed control but no very marked benefit from the maintenance of a soil mulch for onions. If the soil crusts readily, cultivation is necessary while the seedlings are pushing through the soil and thereafter only when necessary to control weeds or to open the soil to catch moisture that might otherwise run off. The onion is a shallow-rooted plant with a relatively sparse and poorly distributed system of fibrous roots. Deep tillage has no place in onion culture. Double-wheel, push hoes are usually used to straddle the rows of young seedlings and remove weeds close to the row. Later, the single-wheel hoe is preferable. Narrow shovels or teeth are sometimes necessary in heavy soils, while horizontal knives or sweeps are preferred in light soils and mucks for cultivation and weed control.

Many growers cultivate too frequently and too late in the life of the onion. As the plants grow they soon shade the rows completely and thus smother the weeds. Top movers must be used for the later operations, or still more damage to the plants may result. After the tops begin to fall, cultivation should be terminated as it does not improve the yields, but does increase the cost of growing the crop.

On muck soil, cultivation is definitely only for the destruction of weeds and its frequency therefore will depend upon rainfall, temperature, and the prevalence of weed seeds, all of which have a bearing on the number of weeds and their rapidity of growth. Cultivation should be frequent enough to destroy the weeds when small, and will accomplish this more completely in hot dry weather than on cool wet days. If the weeds become large enough to bear seed they should be removed from the field to reduce later cultivation and hand weeding. If a crop is lost through unfavorable weather conditions, poor seed, or from other causes, the land should not be allowed to become foul with weeds but should be planted to a green manure crop, such as oats, rye, or Hungarian millet. This procedure will result in increased onion yields and lower cost of weeding over a period of several years.

Weed control on muck soils represents the greatest single cost in the production of onions; it frequently is 15 to 30 percent of the total. Of the two to four hand-weedings that usually are required before midsummer, the first is always the most tedious, requiring the greatest care, time, and expense.

A very recent method of controlling weeds with dilute-sulfuric acid spray has been tried in New York State, and in Canada, Cyanamid has been used for the same purpose. Other herbicides are now on the market and offer great possibilities in controlling weeds on muck soils.

Moisture Supply for the Onion Crop

It is not customary to use irrigation for onions, except in the areas of the arid west and southwest where it is necessary to apply water by the furrow method to secure a crop. Surface irrigation is almost universally employed for growing the Bermuda onion in Texas, where the application of water should immediately follow transplanting of the seedlings. Too frequent irrigation must be avoided. Onions should receive just enough water to keep them in a vigorous growing condition. Severe thrip infestations are partially counteracted by frequent watering. By withholding the water a short time before harvest, ripening of the bulbs is induced.

On upland soils, and especially the lighter types such as the sand, irrigation is very beneficial, especially during dry periods when the sand may be held from blowing and the crop kept growing. A very good price must be secured, however, to pay for irrigation equipment and water.

The muck soils of the country in general have as much of a drainage problem as they do one of too little water. A few growers attempt to subirrigate by ditches, or through drainage tile in dry weather. Usually the grower is concerned with carrying the water away in the spring, which makes earlier planting possible. Most muck areas must be tile drained before they can be used safely for the continual production of onions. Where ditches can be used, they are placed from 4 to 5 rods apart, or at greater distances if the muck drains well. These lateral ditches are usually from 1½ to 2 feet deep and from 2 to 3 feet wide. Main ditches are from 3 to 4 feet deep and from 4 to 6 feet wide. An adequate outlet is of extreme importance. The ditches must be cleaned out once a year, usually in the spring. Grass and weeds should not be allowed to seed on the ditch banks, and their eradication by chemical weed killers, or by cutting, is an effective means of eliminating insects and diseases that overwinter there.

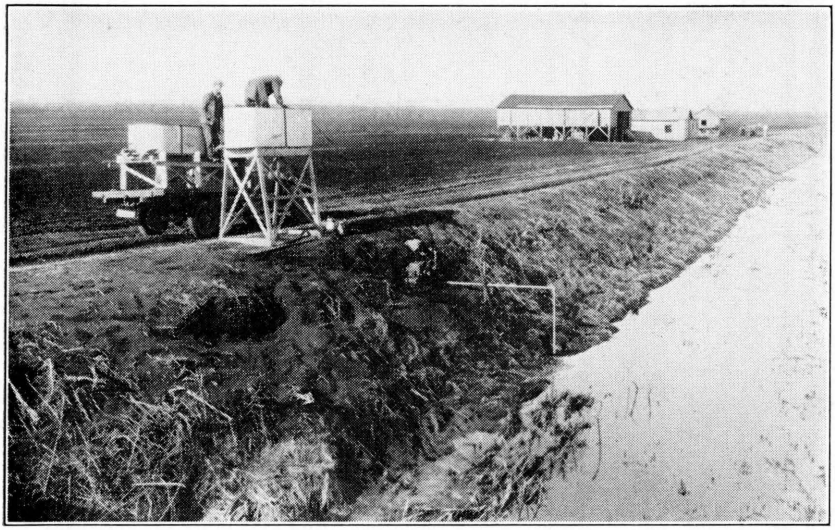

Fig. 18.—Portable water pumping and storage system.
An inexpensive system for supplying water for use in the field for such operations as treatment for onion smut and for spraying. The equipment being light is readily mounted or dismounted and moved by truck to a new location.

In many localities the value of the land used for ditches is so great that it is more economical to use clay tile for the lateral drains and corrugated galvanized pipe for the main lines to the outlet. On most mucks, tile lines 6 to 10 rods apart will provide satisfactory drainage. Only ordinary unglazed clay tile is recommended, and 5-inch tile laid at a depth of 3 feet is satisfactory, except in newly reclaimed muck where the tile should be placed at a greater depth than will be desired later, since new muck settles on the average of about one-fourth the distance between the surface and the tile line within a few years after reclamation.

The proper depth at which the water level in the muck soil should be maintained naturally varies with the compactness of the muck. From 2 to 3 feet seems to be a satisfactory depth during the summer months. The shallower depth requires that the draiange system be adequate to maintain a nearly constant water table during periods of heavy rainfall.

The onion is quite sensitive to extremes of soil moisture. If the water is too near the surface the swelling or "bottoming" of the plant is delayed, with the result that the crop will contain a large proportion of "thicknecks" at harvest. A uniform water level, permitting the onion roots to become adjusted to the supply of moisture, is highly desirable. For this reason, and as a crop insurance measure, it is convenient to be able to place boards as flood gates in the outlet-ditch dams and thereby control the water table during dry weather at the desired elevation.

Where it is impossible to control the water table by means of the drainage system, the more costly overhead sprinkler irrigation system may be used. There exists a close relationship between rainfall and yield of onions except in very wet seasons when the excessive rainfall may reduce the yields through the leaching of soluble nutrients in the soil and for other reasons. This emphasizes the value of irrigation during periods of low rainfall before the stage of bulbing. After the bulbs have fully formed, water should be withheld to insure the maturing of the crop.

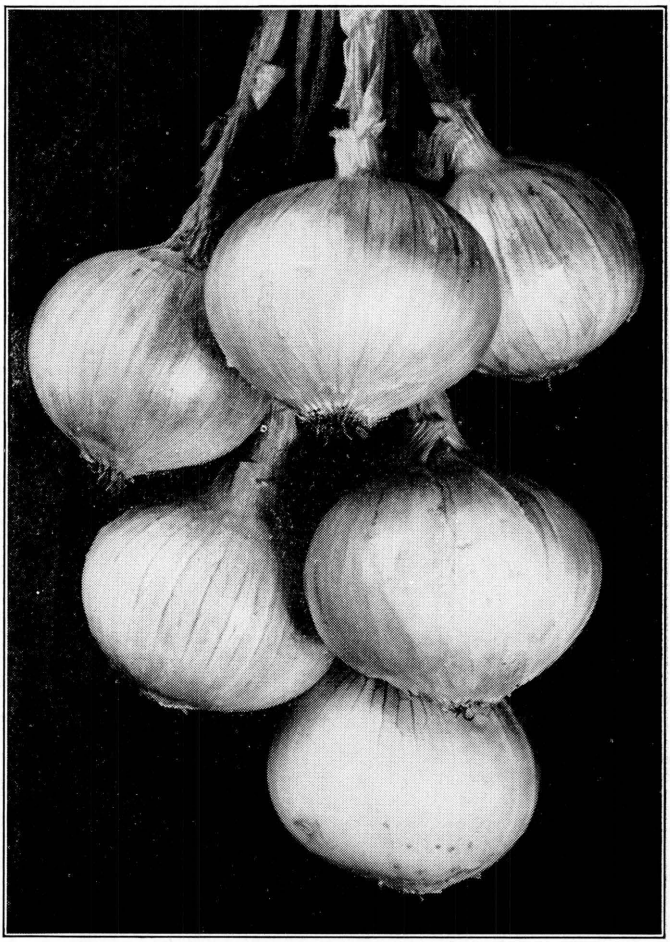

Fig. 19.—The Early White onion.

Experience on muck soil in Ohio (13) has shown that the onion maggot prefers moist soils to dry soils, and the infestation and resulting damage to irrigated onions may be so severe during some seasons as to reduce the final yield to that of the unirrigated land.

Irrigation experiments on the shallow (2 to 2½ feet) muck in Hardin County, Ohio included overhead and sub-irrigation methods using tile lines spaced 12½ feet apart. Water was supplied from a 6-inch drilled well by a No. 2 side-suction centrifugal pump operated by a gasoline engine. Tests indicate that one acre-inch of water could be supplied at a fuel cost of from 45 to 47 cents against a total static and friction head of 34 feet. One gallon of gasoline would deliver from 7,927 to 8,505 gallons of water into the tile lines.

To indicate the rapidity of water movement through this muck soil, one and thirty-seven hundredths inches of water was applied over a 6-hour period, at the end of which the water table 50 feet from the nearest tile line had risen from 1½ to 2½ inches while over the tile lines the rise had been 4.84 inches. From this data it seems safe to recommend spacing tile lines in this muck as far apart as 100 feet and a greater spacing would probably suffice although a longer period would elapse before the total area was irrigated to a satisfactory water-table depth.

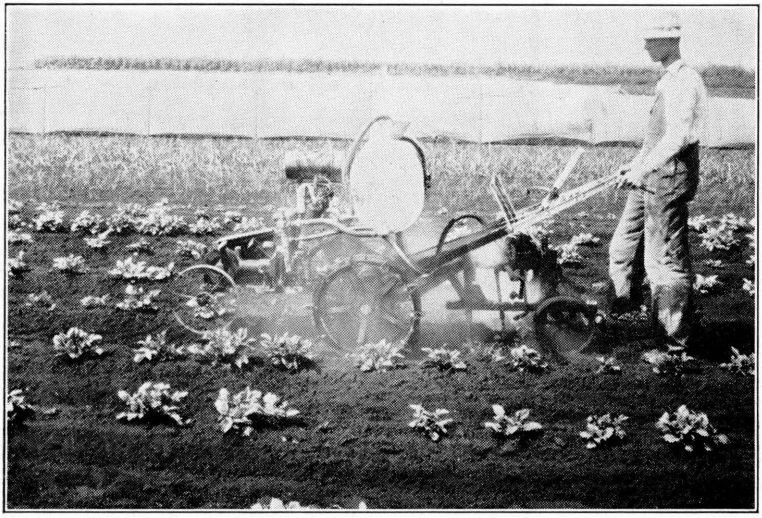

Fig. 20.—Small garden tractor fitted with spray pump and tank. Note the burlap windbreak in the background.

The yields on irrigated plots were very unreliable due to the maggot damage which was always more severe on these areas. Evidence was secured that despite the greater amount of maggot injury on the watered plots, irrigation was economically justifiable during seasons or periods of low rainfall. Sub-irrigation, where it can be practiced, will be superior to overhead-watering during years of heavy maggot infestation.

The use of the sprinkler types of irrigation on onions in the North is usually confined to the production of early crops on upland soils, where the high value of the crop tends to compensate for the higher cost of production and the greater land value.

Protecting the Crop

The onion plant is frost-hardy and when young will withstand temperatures several degrees below freezing. The seedlings are, nevertheless, tender and frail for the first few weeks of their growth, and are easily damaged by winds carrying fine pieces of soil or muck. If the high wind lasts long enough, the entire above-ground growth of the crop may be actually cut off. The damage is usually confined to muck areas, especially those large treeless areas where no natural protection exists and the wind has an unhampered sweep across the entire area.

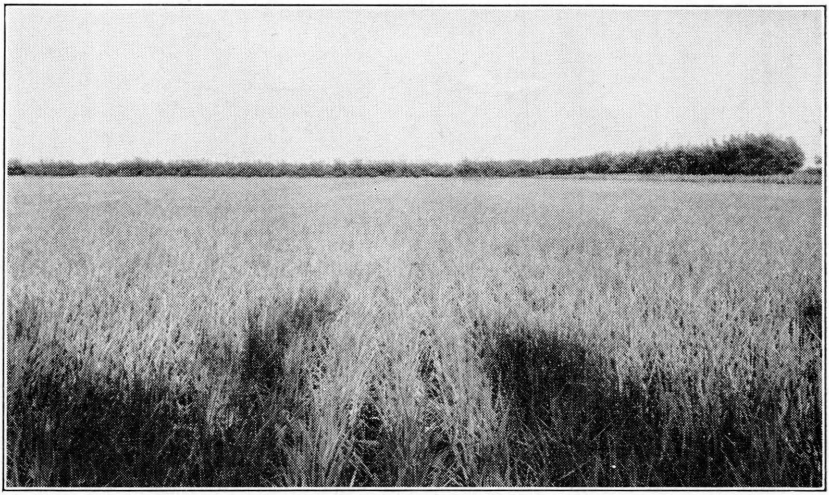

Fig. 21.—A perfect field of onions bordered by a willow windbreak. Note the shading of onions in foreground, one disadvantage of tall tree windbreaks.

The onion seedling, being so tender and so sensitive to damage in its first stages of growth, requires protection immediately after the seed is planted, for once the plants are up and the wind begins to blow it is too late. The crop may be ruined in a few hours.

The principal way of protecting plants from wind damage is to reduce the velocity of the wind. For large areas, it is advisable to plant permanent tree windbreaks, various willow species having proved best. Willow grows faster than other types of trees, and produces a dense growth which will bush out after pruning at any height. Two varieties of Willow are preferred: the Green Willow, (*Salix amygdalina* L.) first used in Ohio; and one of the Basket Willows, (*Salix purpurea* L.) a low growing variety widely used in New York State. Both are easily established from cuttings or slips 3 or 4 feet long, obtained at the time of pruning the older trees. They are driven into the muck with a mallet at a spacing of approximately 1 foot. The breaks are planted from 40 to 80 rods apart in the fall, and in a north and south direction to furnish protection from the prevailing westerly winds.

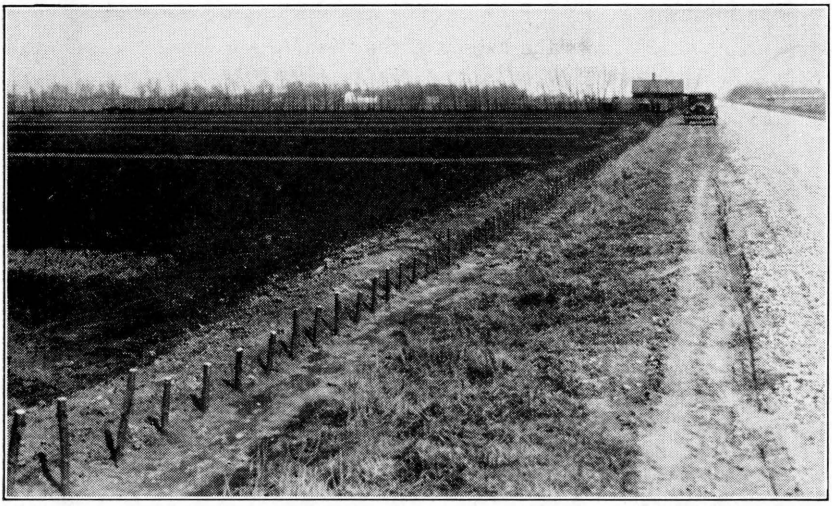

Fig. 22.—A newly planted windbreak. Three foot lengths of willow tree trimmings have been driven into the muck. Note the rye windbreak strips on the left.

On small areas, and usually between permanent Willow windbreaks, removable barriers 100 to 150 feet apart are used. Slat fences similar to the snow fences used by state highway departments are satisfactory, and have now replaced the older burlap fences. Winter rye strips are occasionally used, but harbor insects and diseases over winter, and are not preferred.

One of the best and cheapest methods is to sow spring rye or barley in drill rows 3 to 4 feet apart, interplanted between the rows of onions. Rye is not frozen so readily as is barley. The interplanted grain must be cut off just below the surface of the soil when it is about 10 inches high; otherwise it may require carrying off the field. Either grass, when necessary, may be planted in strips of 5 or 6 rows, 100 feet apart, and the same area later disked and sown to a cash crop such as carrots.

John Stambaugh of Plymouth, Ohio is credited with originating one of the most ingenious methods of wind damage control. When sowing onions, 8 rows are left unplanted every 48 rows across the field. This area is merely plowed with one deep (16-inch), wide (24-inch) furrow which throws up a ridge of muck to stop and hold the blowing soil. As soon as the danger of blowing muck is over, the 8 foot strips are disced to level them and sown to carrots with a gang drill. In this way no economic loss is sustained in controlling the possible wind damage.

Several other methods of controlling wind damage are useful under certain conditions. To mention a few, the growing of green manure crops to be plowed down to increase the soil fiber; sub- or overhead irrigation to maintain a moist soil surface during periods of blowing; the practice of deep plowing to bring to the surface more raw muck; spring instead of fall plowing; the use of a heavy roller on the fields before seeding; ridging of the soil between the crop rows. Judicious use of one or more of these methods may spell the difference

between a good crop and no crop in many cases. It is well to remember that a windbreak protects or checks the velocity of the wind for a distance to the leeward of about 20 times the height of the windbreak. For low windbreaks, the figure is more nearly 10 to 15 times the height of the windbreak.

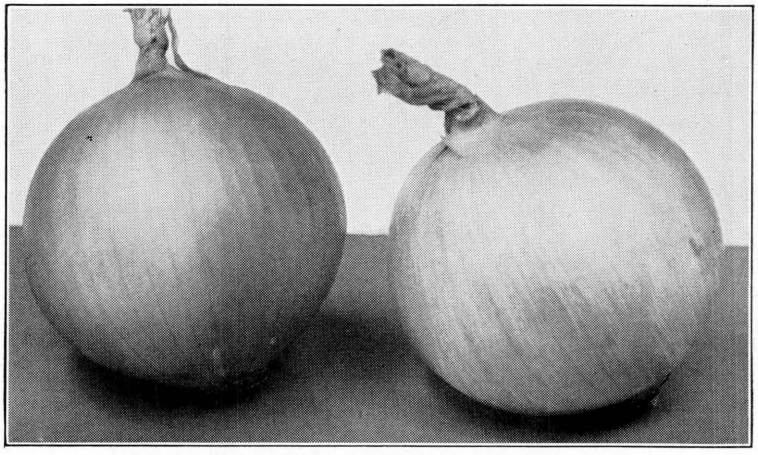

Fig. 23.—The Sweet Spanish onion.

THE SPECIALIZED INDUSTRY OF ONION SEED AND SET PRODUCTION

The production of onion seed and sets of the highest quality and purity is a specialized industry although many growers of commercial onions at times grow their own seed. This seed may be grown to advantage in Ohio where growers are annually producing considerable amounts of high grade seed. Whether there is a deterioration in type and strain of onions coming from seed continually grown in the far West is a question, although many seed growers make it a practice to renew their seed stocks by frequent importations of high-class seed grown in the East or North. Onion sets are also grown in Ohio.

In the last analysis, the production of onion seed and sets of good quality requires special attention seldom supplied by the average commercial onion producer and therefore most of these growers prefer to buy their planting stock or at least contract for its production with those making some effort towards specializing in this field.

The greatest advance in onion seed production is soon to come by way of introducing hybrid vigor in onion seed through well known methods first applied to corn. There are possibilities of close to 50 percent increases in onion yields by this method of seed production. Dr. H. A. Jones of the United States Department of Agriculture and cooperators from various onion growing states are now improving onion varieties and methods of seed production which will bring about these revolutionary changes. Onion seed growers may now utilize these newer methods of onion seed production in a simplified manner outlined in U. S. D. A. Technical Bulletin 874. Various seed companies are also developing hybrid seed.

Onion Seed Production

The production of seed for the larger commercial onion growers may well be intrusted to certain growers within each community who are better equipped than others for the growing and handling of the seed. It has been found that carefully grown seed planted in the same general locality in which it is produced will give better results than seed brought from a distance. This is especially true in northern localities, where the season of growth is short, as southern-grown seed requires a longer season for its maturity. In table 12 is given the yield of Ohio Yellow Globe onions on muck soil in northwestern Ohio from seed which was grown in the same locality and in other more distant locations.

TABLE 12.—The effect of seed source on the yield of Ohio Yellow Globe onions. State Muck Crops Experiment Farm.

Growing season of onion bulbs	Location of seed source	Yield of bulbs in bushels per acre
1932	McGuffey, Ohio	556
	Brighton, Michigan	553
	Gun Lake, Michigan	444
	Exact location unknown, California	308
1933	McGuffey, Ohio	490
	Hamilton, Indiana	458
	Brighton, Michigan	439
	Exact location unknown, California	425
1934	McGuffey, Ohio	530
	North Madison, Ohio	468
	Exact location unknown, North Carolina	389
	Savedge, Virginia	373

The onion seed grower supplying his own community has the advantage of being able to select seed bulbs of a uniform type year after year as requested by his customers and in so doing establish a definitely superior strain. The stock onions may be chosen from the entire marketable crop of the community, which permits the selection of enough bulbs of the type desired for seed. Thus the method of selection as a means of improving the onion is most effectively used with no waste. The commercial onion-seed grower, where the bulbs are grown exclusively for seed purposes, does not find it profitable to discard all those that do not conform to the desired type. If he is short of bulbs for seed purposes he may go into the market and purchase the best obtainable to make up the deficiency. Seed from well and widely selected bulbs at $2 per pound will be cheaper in the end than seed at 50 cents a pound that has come from a miscellaneous lot of bulbs taken as they occur without selection.

Although 2 years are required to obtain first a crop of "mother bulbs" and then the seed from these bulbs, where the seed grower has access to commercial crops of bulbs from which to make his "mother bulb" selection, he need only store the bulbs until spring and plant them for the seed harvest.

The mother bulbs are grown, harvested, and stored in the same manner as those intended for marketing, except that more care should be taken throughout.

Thompson and Smith (38) have shown that storage temperatures markedly influence the percentage of plants going to seed, and they recommend storage of all varieties at 40 to 50 degrees F. Where it is necessary to hold the bulbs at temperatures of 30 degrees to 32 degrees F. during the winter, a shift to about 45 degrees to 55 degrees F. for a few weeks during the latter part of the storage period should stimulate development of seed stalks. The grower should have a clear-cut ideal of the exact shape, form, color, and general characteristics sought in the variety being grown and to grow seed from such bulbs for the greatest possible number of generations. Improvement in the onion by this method of selection comes from making two selections of bulbs, one consisting of but a small number of the very finest and most ideal bulbs from which to produce the stock seed to be used the following year for the growing of the seed bulbs, and the other to include the bulbs from which to grow the supply of seed for the market. By keeping the very best stock separate and using the product for propagation, the entire strain will be gradually improved. Bulbs a trifle below the ideal market size, or about 1½ to 2 inches in diameter, are the most profitable for seed production.

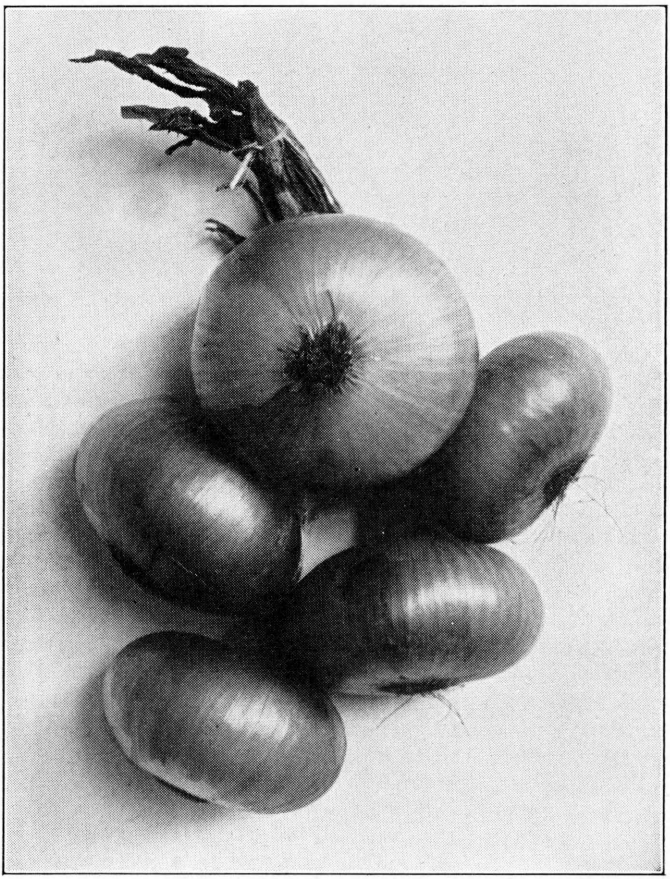

Fig. 24.—The Yellow Danvers onion.

Soils and Soil Preparation for Seed Growing

Rich bottom land such as a sandy loam is preferred for the production of the "mother bulbs", while the seed crop is usually grown on a well-drained upland soil, preferably a fertile loam. Weed-free wheat or corn land containing an abundance of lime is well adapted to seed growing.

No fresh stable manure or green vegetable matter should be turned under directly before planting, but rather a medium application (not more than 1,000 pounds to the acre) of commercial fertilizer containing a small percentage of nitrogen and from 6 to 8 percent of both phosphoric acid and potash. No experimental evidence is available on fertilizing the seed crop and recommendations are therefore not specific. Many seed growers believe muck soils are not suitable for the production of onion seed. However, some very fine seed has been produced on this type of soil when little or no nitrogen was applied, but care was taken to apply plenty of potash; 300 to 350 pounds of muriate of potash per acre.

Planting and Care of Seed Bulbs

The soil and applied fertilizer in which seed bulbs are to be planted should be disked or harrowed until in good tilth. The field should be marked off in rows 2½ to 3½ feet apart with some tool which will make a furrow 3 to 4 inches deep, in which the bulbs should be placed root downward, by hand. Planting depth is of importance, in that considerable lodging or breaking over of the seed stalk may result when bulbs are set too deep. Since it is the aim to have about 4 inches between bulbs, they should be placed from 5 to 6 inches apart, center to center. This will require from 150 to 250 bushels of bulbs per acre, depending upon the size of bulb.

The row furrows are leveled, leaving the bulbs covered by a small amount of soil. As growth proceeds the soil should be drawn around the bulbs to form a support for the seed stalks. Shallow cultivation to control weeds only is all that is required and it should be performed to work the soil toward the plants. When cultivation is no longer needed it is sometimes necessary to work through the field after the seed heads have formed to remove weeds and draw the soil around the plants so the stalks will stand erect and prevent the blowing over of the seed heads before harvest.

Gathering the Seed

The color of the seed is no indication of maturity and it is therefore necessary to wait until the first formed seed is just ready to shatter. At this time the youngest seed in the head will have passed from the milk to the dough stage and thus will ripen properly. It is usually the practice to make two or three cuttings of the seed heads, only about 20 percent of the heads being removed at the first cutting. In harvesting, the heads are cut one at a time by hand, with a very short piece of the stem attached, and dropped into a burlap sack supported around the waist of the person doing the cutting. The bags are hauled to the curing sheds usually 3 or 4 hours after they are filled.

Curing the Seed Heads

The curing or drying of the seed heads may be carried out in any well ventilated building, or even in the open, in localities where rains do not occur during the curing period. Wire-bottomed racks or trays placed one above the

other or on permanent shelf racks are common. Placing the seed heads on canvas on the floor limits the quantity that can be cured in a given area since they must be stirred at least once a day, and oftener if spread more than three heads deep. In damp weather more frequent stirring will be necessary. The main essentials are to spread the heads thinly and to give free ventilation. The seed will shatter upon stirring and finally reach the floor. Seed heads may be dried artificially in corn dryers.

Threshing and Cleaning Seed

Threshing and cleaning of the seed should be done as soon as the seed heads are sufficiently dry, although many growers defer this operation until quite late in the fall. On a large scale, especially equipped threshers are used and on a small scale the seed is beaten out with a flail or rolled out with wooden or rubber rollers.

The special threshing machines have a fanning attachment which removes most of the trash. Any method of threshing must prevent undue breakage of the "button" to which the stems of the flowers are attached, since these buttons have the same specific gravity as the seed and cannot be separated easily from them if they are broken into pieces the same size as the seed.

After threshing, a portion of the trash is removed from the seed by fanning and screening. For more complete cleansing the seed may next be run through gravity separators. There is always some good seed remaining in the litter of trash and light seed. This last separation may be made by floating in a trough or in tubs of water, where the heavy seed sinks to the bottom and the lighter seeds and trash float off. This operation takes some time, with thorough stirring, to remove all of the lighter seed.

The heavy seed which sinks is lifted out immediately and spread out thinly to dry. The good seed should not be left in the water more than 30 minutes and should be thoroughly dried in from 3 to 6 hours. Occasional stirring will hasten the drying and the seed should be at least partially dry before leaving it for the night or during damp weather. It is the usual practice to run the seed through the fanning mill once or twice more to remove completely any inferior seed still present. If fairly rapid drying is not possible it is better to depend entirely upon cleaning by machinery. It is unsafe to bag seed in large quantities unless it is thoroughly dry.

Returns from Onion Seed Production

The production of onion seed is usually on a specialized contract basis. Only on this basis is there ever much profit. There is, however, an increasing demand for high grade onion seed of improved types for which the grower is glad to pay above-average prices. The yield of seed from standard mother bulbs is usually 2 to 3 pounds for every bushel of bulbs planted, or about 400 pounds per acre. Good growers are known to secure 800 to 1,000 pounds of seed per acre in favorable seasons. The price of the seed varies widely, depending upon seed carryover, supply, and demand. Fifty cents per pound is minimum and 1 to 2 dollars per pound is not uncommon. Occasional years, good seed brings 5 dollars per pound. With the land being occupied 2 years for each seed crop and considerable expense being required for bulb storage and hand labor, the returns from this crop are attractive only when choice seed is produced to sell at better than average prices.

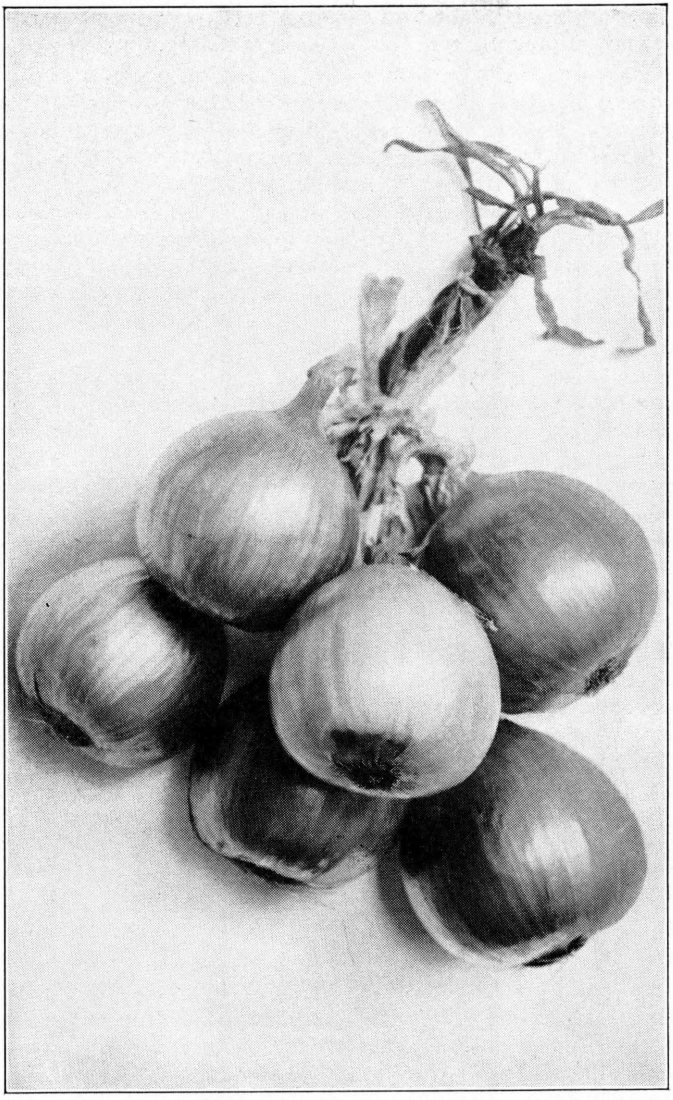

Fig. 25.—The Ohio Yellow Globe onion.

Seed for Onion-set Growing

Onion-set growers require large quantities of seed and therefore are interested in securing it cheaply. It has been the practice to select the well matured, small-necked, uniform shaped, over-sized bulbs from each crop and store them over the winter for use as mother bulbs the following spring. Farmers located some distance from the set producer contract to raise the seed

on land in their general farm rotation, with the result that it is usually disease-free and of good vitality. The large seed companies are growing an increasingly larger proportion of the Ebenezer seed.

It is through the utilization of over-sized set bulbs which produce a large quantity of seed per bushel and through the growing of the seed crop by general farmers that the cost of the seed is kept low. Occasionally a second crop of seed is obtained from a single setting of bulbs by leaving them in the ground over winter, sometimes with slight protection. This practice is not recommended except under special conditions, as where the land is not valuable or where it is particularly desirable to obtain an additional quantity of seed. The prospects for a crop may be best evaluated in the spring and they should indicate at least a 60 percent stand or the field should be put to other use.

Onion Seed Storage

Onion seed does not store well beyond 1 or 2 years unless it receives special treatment. However, well matured seed with a high initial germination will always keep better than poorly ripened seed with a low germination. High humidity and temperature causes onion seed to lose its vitality very rapidly, especially after the second year. Low temperature is of more importance than a low moisture content of the seed in prolonging storage life. A storage temperature of 34 to 36 degrees F. seems most desirable. A cold dry attic is the most practical storage location for small lots of seed. If possible the seed should be reduced to 6 percent moisture and stored in moisture-proof bags.

In view of the relatively high value of onion seed and the importance of high quality, it is a good economic practice to place onion seed in cold storage. The cost for storage should not exceed 1 cent per pound of seed. Without cold storage, hundreds of pounds of seed are a complete loss each year. When onion growers are unable to plant seed which is on hand, the seed may be saved until the next season by proper storage. The storage of the seed at room temperature cannot be depended upon to retain viability of commercial value more than 2 years. Tests carried on by Beattie (4), and others revealed that seeds 7 years old, stored dry in sealed containers at 20 degrees F. suffered no significant loss of vitality as compared with fresh seed.

Production of Onion Sets

Onion sets are small, under-sized bulbs which will produce a large onion upon planting. They are essentially starved onion bulbs, under-sized due to competition for plant nutrients and to crowding. Their growth has been arrested by these conditions and they fail to produce seed stalks during the second year of growth.

The onion set industry is not large, utilizing not more than 3,000 acres of ground each year. The sets are sold throughout the country for growing small areas of onions, mostly in home gardens and where a very early crop is desired.

The sets can be grown in any part of the United States where the soil is adapted to general truck crops. However, the industry is pretty well confined to localized areas around Louisville, Kentucky; Chicago, Illinois; Greeley, Colorado; and Toledo, Ohio.

The land for growing the sets should be prepared in the same manner as for regular crops of onions. The area selected should be free from weeds and in a reasonably high state of tillage.

The adaptation of a 2- or 4-year rotation with other farm crops is advisable. If manure is applied it should never precede the crop of onion sets. A small quantity of commercial fertilizer is always profitable. Between 500 and 1,000 pounds of a mixture containing 4 or 5 percent nitrogen, 10 to 12 percent phosphoric acid, and 6 to 8 percent potash is satisfactory.

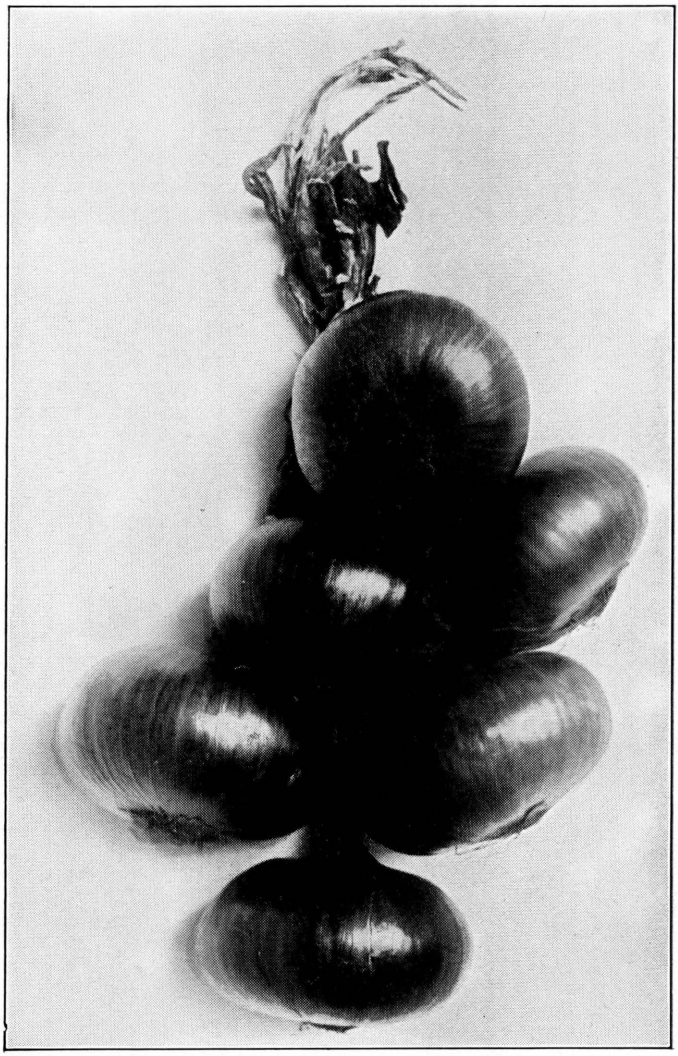

Fig. 26.—The Red Wethersfield onion.

In brief, the seed is sown either in single drills 9 inches apart, using 65 to 85 pounds of seed per acre, or in broad rows 7 to 14 inches apart, wherein the seed is scattered in a belt 3 or 4 inches wide, or placed in 4 or 5 drills an inch apart within the belt which may require up to 120 pounds of seed per acre. The size of the set is largely regulated by adjusting the rate of seed sowing to the fertility of the soil.

Cultivation of the crop is frequent to completely control weeds, but it is discontinued before the sets show any tendency to ripen. Two or more hand weedings are always necessary and should be continued until the onion tops shade the ground. If the weeds once become well established there is little hope of saving the crop.

In harvesting sets they are first loosened by means of a cutter or forked attachment on a wheel hoe and then pulled by hand. If they are harvested before field-ripening they must be cured in the field in windrows, the sets being protected from sunlight and rain by their tops. The general practice is to allow the sets to ripen before lifting, then the tops are twisted off by hand, the sets cleaned on a screen and placed on stacked trays either in the field or in a building where a fan may force heated air over them for rapid drying.

It has been found that the sets store best at a temperature of 30 to 32 degrees F., and when stored at the more common temperature of 40 to 45 degrees F. the yields are reduced and there is a marked increase in the percentage of seeders and double onions.

There are several kinds and sizes of onion sets. The true sets, which should be ½ inch or slightly less in diameter to insure the absence of seed stalks, are sold most universally as yellow sets. Some white and a few red sets are offered for sale. Those much smaller than ½ inch are apt to produce weak plants. Bulbs from ½ to ¾ of an inch in diameter are sold as "picklers" and from ¾ to 1½ inches are sold as "boilers" or "stewers". Several bulb shapes are included in the sets of each color as well as several varieties of each shape. This may be partially explained by the fact that they are sometimes grown from left-over seed.

A few sets are produced from various types of multiplier onions. The true multiplier onions make no top sets and rarely produce seeds. Their large bulbs segregate to produce small bulblets which when planted in the fall in the North, produce early green onions, or when planted in the spring in the South produce large firm dry bulbs.

Shallots (not true shallots) or Jersey shallots are also "multiplier" onions, the segregated bulbs of which are sold as seasoning onions.

GROWING GREEN ONIONS FOR BUNCHING

The growing of young onions for sale or home consumption in early spring is strictly a local enterprise, as none are shipped to distant markets. There are large quantities of green onions grown and sold by market gardeners in close-by markets.

All three methods of propagation of the onion are employed in producing the green onion crop. In the North, the earliest "bunchers" are secured from the top sets of the Egyptian tree onions which, because of their hardiness, may be planted in the fall. The majority of the northern crop, however, comes from dry sets planted as soon as the frost is out of the ground in the spring.

A continuous supply of green onions is obtained by successive sowings of seed in the open ground and the "bunchers" are harvested during the summer and fall.

Fig. 27.—The Extra Early Red Flat onion.

In the North, the Egyptian tree onion top-sets are planted in the fall at least 6 weeks before freezing weather. The sets are planted quite close together in trenches about 4 inches deep and 12 to 14 inches apart. As they start to grow the trench should be gradually filled. Partially-grown onions will result by freezing weather, and they will resume growth in the spring and in mild winters will grow more or less as the temperature permits. Where

the winters are severe it is necessary to provide some protection after the ground is frozen; either a little straw, loose manure, leaves, shredded corn fodder, or other easily obtainable mulch. If the area devoted to such a planting is protected on the windward side by means of a windbreak, such as a shrub or tree planting, board fence or corn fodder, the crop will be ready for harvesting a little earlier than if left exposed. Some of the crop may be left unharvested for producing the sets for planting the following fall. The green onions of this variety must be marketed very early to avoid development of extremely strong flavor and very tough flesh.

The most popular method of producing bunching onions is from dry sets of the common onion grown in the North. Enormous quantities of sets are produced around Chicago and are shipped all over the United States, mostly for use in home gardens. As soon as the ground can be prepared in the spring, the sets should be planted with 1 foot of space between the rows, 1 to 2 inches apart.

In general, gardeners are not acquainted with the excellence of the "bottle onion" type as a green bunch onion. It has been grown mainly in Pennsylvania and Ohio for many years. Its excellence as an early green onion is due to the extra long white edible portion and its unsurpassed mild, sweet flavor. When not consumed as a green onion it may be left to produce a dry onion for slicing which keeps well in the ordinary house cellar.

Occasionally, plants (seedlings) of the foreign mild-flavored varieties are planted to produce large green onions of exceptionally mild flavor.

As an economical method of producing green onions for sale after the higher-priced early crop is off the market, successive sowings of 20 to 30 pounds of seed per acre may be made and the young green shoots harvested during the summer and fall.

Chives, which are propagated by the division of the clumps, are a perennial and are bunched and sold at all periods of the growing season. They are quite mild.

The bunching of green onions requires considerable time and care and the price obtainable for the crop does not encourage wide production by commercial growers. Removing the outer scale results in a whiter, more attractive product but is seldom justified because of the higher labor cost. Modern washing and tying equipment lowers the cost of preparing the crop for market.

HARVESTING AND STORING THE CROP

Harvesting

Onions are harvested either as green bunch onions or as mature bulbs. When an onion reaches pencil size and until it begins to bulb, it may be pulled by hand, trimmed of roots and outside skin, bunched, and taken to market.

All other onions are harvested when mature; that is, when upwards of two-thirds of the tops have ripened at the necks and fallen over. The tops of properly grown onions will turn yellow and wither at a point approximately 1 inch above the bulbs, thus causing the foliage to drop to the ground.

In the North, where most of the crop is stored, they will keep better if allowed to become fully ripe before pulling. Immature onions are easily injured and therefore the tops should ripen down (die and shrivel) and the outer skin of the bulb should be dry before they are pulled. Since there is

some danger of second growth if rains occur at this time and early onions some seasons bring good prices, growers of large acreages start harvesting when the crop is two-thirds ripe. Occasionally it is necessary or advisable to break down the remaining tops with a light roller or drag before lifting the crop, although this may increase losses from neck rot. Timely, prompt handling is always important. One or more unfavorable growing conditions occasionally cause the onion top to remain green and thickened near the bulb and ripen progressively from the tip downward. Such onions are called scallions and occur most frequently during excessively cold temperatures for prolonged periods. Improper fertilization and disease and insect attacks, especially thrips, may cause scallions.

Curing

It is almost a universal practice in the North to dry partially or "cure" the crop in the field. The bulbs are lifted by hand or with a lifter (small plow) and thrown into windrows. Two or three rows on each side of the person pulling are brought together in the windrow in such a way that the tops partially shade the bulbs and maintain a bright, attractive color. Exposure to sun and weather would result in the development of a green pigment, fading or discoloring, and even sunscald. In irrigated sections, water may be used to soften the ground a day or two before the harvesting, which permits the bulbs to be pulled easily.

This preliminary curing is allowed to progress for from a few days to 2 weeks, depending upon the weather. To secure bright, attractive bulbs, an important factor in securing the best prices, the crop should not be exposed to the weather longer than is absolutely necessary. This is especially important with white varieties, which are sometimes cured under cover, since they are especially susceptible to smudge disease. It may be necessary, if the onions are wet by rain, to turn them with a rake or fork in order that drying may proceed. No factor is of greater importance than care of the crop at this time in maintaining the high quality of well-grown onions and influencing the price they will bring.

Onions that are to go into storage need thorough curing and after topping with sheep shears or with machine toppers to within ½ to 1 inch of the bulb, are most frequently left in crates either in the field or near the storage until freezing weather. The top layer of crates is covered water-tight usually with roofing paper.

Cleaning and Grading

After the onions have cured for at least 3 or 4 weeks or until danger of freezing, they are run over a sorting rack made so that the bulbs can be sorted into two or more grades based on size. When only one market grade is made the slats of the sorting rack are 1¼ inches apart, and for two market grades a second section divides the bulbs between ¾ inch and 1¼ or 1⅜ inch. During the grading all "thicknecked" and injured or decayed bulbs are picked out, while the dirt and small bulbs fall through the slats. The small sizes are sold as "picklers". At this time the dry, loose outer scales are rubbed off, leaving the bulb bright and clean.

Careful grading according to federal standards pays the grower or operator well for his trouble; often as much as 50 percent more is obtained for the graded than for the ungraded portion of the crop. In handling onions it is the

rule to pass them over a screen each time they are moved, as in this way the loose skins are removed and any soft or decaying bulbs may be sorted out. Better grading methods are likely to be demanded by the consuming public within a few years, while Federal inspection at the shipping point is proving of great benefit as a protection for both the shipper and the buyer.

Packing and Marketing

Onions are packed and marketed in a great variety of crates and bags, and in some localities baskets are used. There are three size grades recognized: those 1¼-inch and over are primes, from ¾ to 1¼ inches are seconds, and all smaller bulbs are classed as picklers. Bushel hampers or baskets are used in some early onion districts for marketing the crop, while slatted crates are used in Texas for Bermuda onions.

Bags are the most common shipping containers, as they are cheaper than any others and the newer orange-colored open-weave paper fiber sacks holding 10, 25, 50, and 100 pounds of onions, stamped with the grower's or shipper's brand name, make a very attractive pack with considerable advertising value.

Fig. 28.—Sweet Spanish onions being bagged for shipment to market.

A very large proportion of all onions go from the field at once into the hands of local buyers or local agents of city dealers or are consigned to commission men in the control markets. This is true both of early and of late onions. A detailed discussion of financing and marketing onions will be found in publications of the U. S. Department of Agriculture.

Storage

Most onions move to storage in October and by the end of November have either been shipped to market or placed in winter storage. The storage of this crop is rather expensive, for the mere possession and holding of the onions must be financed, and the waste from storage, even under the best conditions,

is considerable. Approximately 30 to 50 percent of the Northern onion crop is placed in storage through purchase from the smaller growers by the larger growers, dealers, or speculators. The holding of a portion of the onion crop in storage, or the mere possession of a storage, is quite likely to return a profit to the owner, especially during those years when the total production of late onions is small. The prices offered for the onions at harvest are frequently higher in localities where there are storages to hold a considerable portion of the crop.

The storage owner has some control over two of the three important factors affecting the probable outcome of onion storage ventures; that is, storage losses and the grade and quality of the onions stored. The third factor, price trends, is of extreme importance and must be judged with a great deal of care, as is usually the case with any highly speculative venture.

Storage losses are dependent almost entirely upon the grade and quality of the crop stored, and upon the management of the storage house. Cleaver in Indiana (10) found losses in U. S. No. 1 grade onions were 40 percent less than for onions from the same lots that just failed to meet the grade requirements. Losses in storage do vary greatly in different years, even though temperature and humidity are the same, which points towards conditions under which the crop is grown as being responsible for much of the storage losses. For example, it has been shown that late-maturing onions sprout more readily than early-maturing onions. Also, losses from decay are less in early-maturing onions.

Sprouted onions account for the largest part of the shrinkage in storage. The U. S. Department of Agriculture (42) has determined that sprouting of onions in storage seems to be influenced little by humidity, but is increased as the temperature is allowed to rise. Rotting, however, responds only to rise in humidity and is little affected by temperature. Decay is little affected by either temperature or humidity.

Onions pass through a period of rest for 2 months after harvest and are not likely to grow regardless of storage conditions. It is the later storage period, or from approximately January 1 to March 1, that is important. The temperature of the outside air is lower during this period but there is likely to be two or three times as much sprouting in the later period unless care is taken to maintain as low a temperature as is possible without actual freezing.

A temperature of 32° F. and a relative humidity of 64 percent in the storage has resulted in the least loss of the crop and conditions as close to these as possible should be maintained, especially after the first of January. To secure these desirable conditions, storage houses should be constructed above ground and be supplied with vapor-proof paper linings, insulation, and ventilation openings (5). The onions should be stored only in slatted crates and stacked not much above the eaves of the storage, since temperature and humidity are thus more easily controlled. Ample insulation in the roof will eliminate any tendency for moisture to condense on the ceiling and drip onto the onions. Care in ventilation is very important for never should damp air or air much warmer than the onions be allowed to enter. Moist air such as occurs during damp, foggy, or rainy weather will cause the onions to become damp and actual condensation (sweating) on the surface of the onions will occur. When the temperature in the storage is considerably higher (15° to 30° F.) than outside, ventilation will be beneficial even though the outdoor air is damp, for low temperature is always more important than low humidity in the keeping of the onion.

The practice of heating the storage air either to raise its temperature or to dry it, should be used only as a last resort. It is much safer to depend on ample insulation for protection against freezing and thorough ventilation during the drier, colder weather to prevent sweating, or to dry onions that become wet. Re-screening is of value to reduce losses of onions found to be wet from rotting and decay.

Provided the storage is properly constructed and managed, losses may be kept to a minimum only when well-cured and graded onions are stored. Field sanitation will eliminate much of the loss due to decay. All decayed and cull onions and other refuse from screening the crop in the field should be destroyed by burning or be removed, to eliminate future sources of infection for neck rots and more especially bacterial soft rot.

White and Sweet Spanish onions are more difficult to store successfully than are the late-maturing yellow varieties (33). More careful handling and thorough curing before storage is necessary with these varieties. More attention to low humidity is also necessary with the white varieties, since they are more subject to rotting and to decay caused by relatively moist air. In some instances, a drying agent such as calcium chloride is used to absorb the moisture from the atmosphere, especially in cold storage warehouses.

Cold storage for onions is increasing in importance each year. In these storages it is possible to keep the onions dormant throughout the storage season and thus eliminate sprouting, the major cause of loss.

COSTS AND RETURNS IN PRODUCING ONIONS

The few studies that have been made on costs and returns in producing onions all agree in showing wide annual variations as well as between growers. The variations in net returns to growers are usually the result of differences in price, in economy of production, and in yield per acre. Invariably, high onion yields are associated with large applications of fertilizer, good seedbed preparaton, moderately early seeding, a large amount of weeding and cultivating, and, in the case of muck soils, a short period of years since the muck was first cultivated.

Onions that grade U. S. No. 1 will bring more, 50 percent more during 1923-24 in Indiana (18), than onions nearly as good except for small percentages of off-grade bulbs. Thus careful grading of onions before they are placed in a car for shipment adds only slightly to the cost of marketing the crop but increases the net returns to a large extent.

The average yield of onions is around 200 bushels to the acre, although yields of 400 to 600 bushels are not uncommon. Because of variations in the cost of labor, tools, fertilizers, seed, and other materials and the many factors involved in the production of an onion crop, it is impossible to give definite cost and profit figures. The demand for onions is relatively inelastic as compared with many other farm crops. A shortage in supply usually results in a more than proportionate increase in price. For this reason there are often wide fluctuations in onion prices from year to year.

In table 13 are given the costs of producing an acre of onions, together with the percent of the total cost of production ascribed to growing, harvesting, screening, and marketing the crop. In addition, there are given the gross and net returns, which together with the costs are 4-year averages (1934, 1935, 1938, and 1941) on 35 to 65 farms.

The table shows man labor to be the largest item in the cost of producing onions (47 percent of the total). The next largest items of cost were onion equipment (10 percent), seed (9 percent), fertilizer (8 percent), sacks and supplies (6 percent), storage and miscellaneous (6 percent). These items constituted 86 percent of the total cost. Nearly one-half the total cost was for growing the onions up to the time they were ready for harvest. A little over one-fourth of the cost was for harvesting, one-twelfth for screening and grading, and one-sixth for marketing.

TABLE 13.—Cost of producing an acre of onions*

	Quantity	Percent of total cost of production					Cost
		Growing	Harvesting	Screening	Marketing	Total	
Seed, lb.	5.6	9				9	$11.62
Fertilizer, lb.	522	8				8	10.21
Manure, tons	0.4						.62
Green manure							.20
Farm labor, hrs.	106	8	4	2	2	16	20.60
Special labor, hrs.	192	13	12	4	2	31	39.55
Horse labor, hrs.	9						.85
Tractor use, hrs.	4	2	1			3	2.95
Truck or auto.			2		1	3	1.93
Farm machinery							.78
Onion equipment		1	8	1		10	13.25
Use of land		4				4	4.95
Sacks and misc. supplies					6	6	7.84
Storage and misc.		1			5	6	7.65
Overhead		2	1		1	4	4.95
Totals		48	28	7	17	100	$127.96

*Compiled from "Economic Aspects of Onion Production in Northern Indiana", 1942. Indiana Agr. Exp. Sta. Bull. 475.

Yield in bushels	$248
Price per bushel	.80
Gross income	198.40
Cost per acre	127.96
Cost per bushel	.52
Net return	70.44
Return per bushel	.28
Return per hour man labor	.44

The yield is the one factor most responsible for high net returns and is more easily controlled than is the price received for the crop or the economy of production. Table 14 shows the effect of yield on net profits secured from various-sized crops of onions grown from sets. The cost of production previous to harvest was the same for all yields and the increased cost of harvesting, packing, and marketing for the large crops was not much more than for the small crops. The total production cost per bushel was thus less the larger the yield per acre.

The storage of onions and their subsequent marketing is a highly speculative business and for this reason most of the onions harvested by small growers in the fall are sold outright to the larger growers and dealers owning large storages. There is considerable shrinkage, including waste and deterioration, in the onions stored. Shrinkage in common storage to February or March frequently amounts to from 5 to 20 percent and is most often about 10 percent. The cost of common storage is from 6 to 10 cents per bushel or per crate or 10 to 20 cents per hundred pounds. The cold storage rates in receiving markets is approximately 5½ to 6½ cents per 50-pound sack with a handling charge of

TABLE 14.—Production cost per bushel and net profits per acre according to yield per acre and price per bushel*

Yield, bushels per acre	Production cost per bushel	Net profit per acre at			
		$0.75 per bushel	$1.00 per bushel	$1.25 per bushel	$1.50 per bushel
150	$1.00	−$36.86	$ 0.64	$38.10	$75.64
175	.89	— 24.71	19.04	31.54	106.54
200	.81	— 12.56	37.44	87.44	137.44
225	.75	— .41	55.80	112.09	168.34
250	.71	10.70	73.20	135.74	198.24
275	.66	23.09	92.64	161.39	230.14
300	.63	36.04	111.04	186.04	261.04

*Onion Culture, 1930. Virginia Truck Exp. Sta. Bull. 72.

1½ cents per sack. The profit in storing onions is dependent to a large extent upon the size of the crop at harvest time, its condition when entering storage, and the cost of storage.

THE ONION AS FOOD

Today the onion is recognized as the chief food plant in which the food is stored in a bulb. The bulbs are dried and cured before storing to develop their characteristic flavor and taste, which are due to the presence of an acrid volatile oil, the chief constituent of which is allyl disulfide. This oil, in moderate quantities, acts as a gastric stimulant and probably promotes digestion, but in large quantities it may give gastric distress. The milder varieties contain less of this oil and thus have a more delicate flavor. Since the oil is volatile, it partially disappears in cooking which increases the ease of digestion and reduces any tendency to cause gastric distress.

The ash constituents of the onion are balanced between acid-forming and base-forming (slightly greater) elements and therefore they contribute little towards the neutralization of acids from other foods.

The bulbs contain considerable amounts of cellulose (considered good for constipation) and practically no starch. They do contain considerable sugar, however. For these reasons onions are often chosen for the diets of invalids and very young children.

Onions are used for flavoring, as a vegetable, for pickles, and in medicine. Although many beneficial properties have been attributed to the onion besides its value as a food, very few seem to have been thoroughly substantiated by medical research.

In order to compare the nutritive value of the onion with other vegetables, a group of nine have been chosen as representative of the wide variety of vegetables commonly eaten today. In table 15 are given the amounts of several nutrients and vitamins in 1 pound of several fresh vegetables.

No claim is made that the onion should be eaten as a rich source of minerals or vitamins. However, it is interesting to note that this vegetable compares favorably with many other vegetables in these respects. Its food energy is exceeded only by the high protein foods such as dry beans and by the high starch food, potatoes. Only the seed vegetables such as dry beans contain large amounts of protein and there is slight difference between the remaining vegetables listed and onions. The same is true of fats. Carbohydrates are

easily secured in many vegetables and again onions compare favorably with those listed. As for the minerals, this crop is not a particularly good source of iron but is well stocked with phosphorus and to a lesser extent with calcium.

TABLE 15.—Nutritive value of 1 pound of certain vegetables*

Vegetable	Food energy	Protein	Fat	Carbohydrates	Calcium	Phosphorus	Iron	Vitamin A	Ascorbic acid	Thiamin	Riboflavin	Niacin†
	Calories	*Gr.*	*Gr.*	*Gr.*	*Mg.*	*Mg.*	*Mg.*	*I. U.*	*Mg.*	*Mcm.*	*Mcm.*	*Mg.*
Beans, dry	1,590	100	7	282	671	2,100	46.7	0	0	2,360	1,415	12.7
Beans, snap	80	4	1	15	190	132	3.3	4,540	15	165	265	0.2
Beets	240	7	1	52	79	127	3.0	300	70	135	75	2.9
Broccoli	75	7	1	11	277	163	2.7	10,000	255	215	465	3.1
Carrots	175	5	1	37	156	150	3.2	28,350	30	240	280	5.8
Onions	210	6	1	44	136	186	2.1	0	45	125	515	0.4
Peas	210	14	1	36	45	250	3.9	1,780	50	835	285	1.4
Potatoes	325	8	1	73	50	186	2.8	150	40	345	190	4.5
Spinach	90	9	1	12	0	204	11.3	27,520	260	410	595	2.7
Tomatoes	100	4	1	18	49	120	2.7	5,780	110	355	200	2.6

*See citations 1, 14, 22, 33 in bibliography.
†Present methods of measuring niacin are not considered accurate for vegetables.

The green leafy vegetables are generally high in vitamins, and onions contain little or no pigment in their edible portions. This vegetable contains almost no vitamin A, an insignificant quantity of niacin, a small amount of thiamin (vitamin B_1), but contains considerable ascorbic acid (vitamin C) and large amounts of riboflavin (vitamin B_2 or G).

The chief virtue of onions is their flavor. All good cooks appreciate the value of onions in preparing tasty meals. For some dishes onions are needed only for flavor, for some they are the chief ingredient, and frequently they are served alone as a vegetable or relish. Liver with onions is a favorite. Onions enhance the palatability of a meat loaf, hash, hamburger dishes, and stews. Onions are tasty in soups, salads, and sandwiches. In fact, there is many a spot on the menu where adding onions makes a good dish a better dish.

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